FINAL REPORT

HARDY LAKE WATERSHED DIAGNOSTIC STUDY

PREPARED FOR JEFFERSON AND SCOTT COUNTY SOIL AND WATER CONSERVATION DISTRICTS

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Executive Summary

EnviroScience, Inc. provided ecological monitoring services to the Jefferson and Scott County Soil and Water Conservation Districts for the purpose of conducting a diagnostic water quality and land use study of the Hardy Lake watershed, located in southeastern Indiana. The watershed is approximately 7,500 acres (3,035.1 hectares) with the lake contributing 741 acres (299.9 hectares). The study was jointly funded by Jefferson and Scott Counties through a grant from the Indiana Department of Natural Resources, Division of Water, Water Resources Development Fund.

Land managers, lake managers, land owners, fishermen, and other lake users had become concerned over a perceived decline in the Hardy Lake water quality. The majority of the concerns focused on suspected sediment and nutrient loading, a declining fishery, macrophyte overabundance, and land use. The primary goals of this study were directed toward identifying problem areas of the lake and watershed, and were as follows:

- Map and evaluate the lake and watershed on a preliminary basis.
- Identify land use practices that may potentially impact water quality/reservoir storage.
- Develop guidance for future studies/remediation
- Develop recommendations for Best Management Practices that will protect and enhance the current resource and surrounding watershed.

The study focused on the tributaries and subwatersheds of Hardy Lake, with some limited lake sampling to characterize the current status of the lake.

Select tributaries and the outlet of Hardy Lake were sampled for biological, analytical, and physical parameters. Sites were selected based on their drainage area, proximity to possible problem areas, and location within the watershed. One round of fish sampling, two rounds of macroinvertebrate sampling, and a habitat evaluation were performed at each of the 5 sites using Federal EPA Rapid Bioassessment and Ohio EPA methods. The biological results were analyzed using various multi-metric indices including the Index of Biotic Integrity (IBI), the Family Biotic Index (FBI) and the Hilsenhoff Biotic Index (HBI). In-field and analytical chemistry, as well as flow and turbidity data were collected at 8 stream stations on selected Hardy Lake tributaries.

Lake monitoring was conducted at 6 sites on Hardy Lake. The “Deep Hole” site was analyzed for the calculation of TSI indices, and five sites at various inlets were used to investigate nutrient and sediment loads from various tributaries. A detailed aquatic plant survey of the lake was conducted to identify problem species and special interest species distributions.
A secondary source review was jointly conducted by EnviroScience and the Scott and Jefferson SWCDs to investigate existing historical data for the watershed. Indiana Department of Natural

Resources fishery reports, USFWS National Wetland Inventory Maps, digital aerial photographs, and other information were compiled for future reference.

A detailed land use analysis of the Hardy Lake watershed was conducted by EnviroScience. A Geographic Information System (GIS) was created for Hardy Lake using information gained from all aspects of the project including secondary source review, biological, and chemical sampling data. Land use was characterized for each major watershed based on aerial photographs, NWI maps, USGS topographical maps, and field verifications. The watersheds were then evaluated using various models to identify potential problem areas and areas of importance.

It was concluded that all subwatersheds studied were somewhat impaired by sedimentation due to land use practices, and select watersheds were impaired by nutrient loading due to agricultural practices. However, overall the watershed was considered in "good" condition with some problem areas. Subwatersheds 4, 5, 9 and 12 were identified as having problem areas in need of restoration. Subwatersheds 1, 2 and 3 were considered important and in need of protection. It was determined that because the lake was currently in a state of mild eutrophy, a restoration of problem subwatersheds could result in a noticeable improvement in overall lake quality.

Lake monitoring data were analyzed using two trophic state indices. It was determined that the lake was in a state of mild eutrophy. Aquatic plant densities and distributions of each species encountered were mapped in a GIS. Coontail and American lotus were found to be the most abundant species in Hardy Lake. The exotic purple loosestrife was found to be established in many shoreline areas.

Best management practices were recommended to address sediment and nutrient concerns within specific subwatersheds. A volunteer monitoring program was recommended to encourage community support of lake restoration. Because of the drought conditions during 1999, continued stream monitoring was recommended to supplement the results of the 1999 study and to monitor any changes within the watershed or lake itself.

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

Hardy Lake is a 741 acre (299.9 hectares) reservoir located in Jefferson and Scott Counties, Indiana. The reservoir was created in 1970 (originally named Quick Creek Reservoir) in an effort to resolve the water supply problems of Scott County and adjacent areas (Lehman, 1987). Currently, the Indiana Department of Natural Resources (IDNR) has an agreement to sell water reserves to surrounding areas when the East Fork of the Muscatuck River cannot meet the needs of the Stucker Fork Conservancy District.

The lake is in the Muscatuck River watershed and is surrounded primarily by rolling woodlands of the state recreation area and a few private residences. Land uses within the approximately 7,500 acre (3,035.1 hectares) watershed include various agricultural activities and isolated woodlands. The IDNR manages the impoundment for recreation, including modern and primitive camping areas, a swimming beach, managed hunting zones, hiking trails, and boating.

Due to increasing concerns regarding the water quality of the reservoir and its tributaries, the Jefferson County Soil and Water Conservation District (SWCD) and the Scott County SWCD jointly contracted EnviroScience, Incorporated to complete a diagnostic evaluation of Hardy Lake and its watershed. The original scope of work was drafted by ACRT in July of 1996. Later that year, EnviroScience purchased the Ecological Services division of ACRT and was subsequently awarded the project pending funding from the State.

Funding was provided through IDNR Division of Water with a grant from the Water Resources Development Fund. The fund supports the Lake and River Enhancement program whose primary goals are to 1) to control the inflows of sediments and nutrients into lakes and streams, and 2) where appropriate, forestall or reverse degradation from these inflows through remedial action (IDNR, Division of Soil Conservation, 1999).

During preliminary meetings with the sponsoring agencies, EnviroScience developed a list of goals for Hardy Lake and the current study. These goals are:

- Map the Hardy Lake watershed, watercourses, and subwatersheds
- Evaluate the watershed on a preliminary basis
- Evaluate the reservoir on a preliminary basis
- Identify land use practices that may potentially impact water quality/reservoir storage capacity
- Map the Hardy Lake aquatic plant community and identify exotic/important species and potential problem areas
- Develop guidance for future studies/remediation
- Make recommendations for Best Management Practices (BMPs) that will protect and enhance the current resource and surrounding watershed

Based on these goals, a study plan was created to provide the most appropriate and efficient use of the project's funds. The study was designed to focus on the tributaries and subwatersheds of Hardy Lake, with limited lake monitoring. Field collections in select Hardy Lake tributaries were initiated in the spring of 1999 and included an evaluation of in-stream habitat, biological sampling for fish and benthic macroinvertebrates, and chemical analysis. Stream sites were chosen by EnviroScience and the Hardy Lake board and represented the major inputs to the lake. Additionally, EnviroScience organized volunteers from the area to collect flow and turbidity readings from the same tributaries during high flow events. Field operations within Hardy Lake included the collection of analytical samples throughout the lake and at the deepest location in the lake (designated as the deep hole). A detailed aquatic plant survey of Hardy Lake was completed during the peak of the growing season. EnviroScience and the Jefferson County SWCD collected additional information through a detailed secondary source review of literature and mapping information. This information was applied to a land use analysis of the watershed and facilitated the development of a detailed Geographic Information System (GIS) database. As part of this task, sediment and nutrient loads were calculated for the major tributaries.

2.0 Methods

The following sections details the methodology used in the Hardy Lake Watershed Study.

2.1 Biological

Biological sampling was conducted on four of the major tributaries of Hardy Lake and the outlet (Quick Creek). Sampling sites are presented in Figure 2-1. Field collections included an in-stream habitat evaluation, fish and benthic macroinvertebrates.

2.1.1 Stream Habitat

During the March, 1999 fish and macroinvertebrate sampling event, a comprehensive habitat evaluation using Rapid Bioassessment Protocols (RBP) as developed by the US Environmental Protection Agency (USEPA; Barbour et al. 1999) was conducted at each of the five sampling sites.

A Physical Characterization / Water Quality Data Sheet was completed and habitat scores were calculated for each site. The habitat evaluation, as developed by the USEPA, is a physical habitat index which provides a quantified evaluation of the lotic macrohabitat characteristics important to fish communities. The index is calculated by assigning scores for each of the

Figure 2-1. Stream sample sites within the Hardy Lake watershed

following ten metrics:

- Epifaunal Substrate / Available Cover
- Pool Substrate Characterization
- Pool Variability
- Sediment Deposition
- Channel Flow Status
- Channel Alteration
- Channel Sinuosity
- Bank Stability (each bank scored separately and combined)
- Vegetative Protection (each bank scored separately and combined)
- Riparian Vegetative Zone Width (each bank scored separately and combined)

Each metric has a maximum value of 20 points, and the sum of the metric scores yield a total score that numerically rates the habitat of a particular stream reach. This habitat evaluation is based on a scale of 200 possible points. The maximum score was determined by the USEPA to represent undisturbed habitat similar in structure to the Hardy Lake watershed study sites. Narrative ranges are given for the overall scores, and scores between 160-200 are considered "optimal" for supporting biological communities; between 110-159 are sub-optimal and indicate minor problems that could affect the in-stream biota; 60-109 are marginal and indicate moderate problems are most likely affecting the biota; and 0-59 are poor indicating major problems are affecting the biological communities. Physical Characterization / Water Quality Field Data Sheets are presented in Appendix A.

2.1.2 Fish

A Smith-Root® 12B Backpack Pulsed Electrofisher was used to sample fish populations at each of the five Hardy Lake tributaries on March 23 and 24, 1999. The output of the unit is adjusted according to the conductivity of the water being sampled. The current flowing through the water is directly related to the voltage applied: the higher the voltage the greater the current. The power output was adequate to representatively sample the smaller individuals, while minimizing adverse effects on larger individuals.

Sampling sites were approximately 100-150 m (328.1 ft) in length, and included all representative habitats within each sampling site. Electrofishing started at the downstream-end of each site and proceeded upstream. The electrofishing crew consisted of two netters; an individual controlling the anode ring, and one person identifying, weighing, and recording specimens from a livewell at the stream side field station.

Immediately after collection, stunned fish were taken to shore where they were identified, weighed to the nearest 1/10 of a gm, measured for length, and examined for external anomalies. Total length was recorded to the nearest 0.10 cm. Mass and length measurements were taken for 50 randomly selected individuals of each species. Length, mass and anomaly data were recorded on EnviroScience Fish Data Sheets. Except for those retained for laboratory confirmation, all collected fish were released upon total recovery from the initial shock.

Fish collected during the course of this study were identified in the field by experienced aquatic biologists. Representative samples having uncertain identity were preserved in borax-buffered 10% formalin and returned to the EnviroScience lab for further examination. The primary taxonomic key for the identification of fish collections from the Hardy Lake area was *The Fishes of Ohio* (Trautman 1981).

The biological community assessment method used to evaluate fish populations in this study was the Index of Biotic Integrity (IBI). The IBI is a multi-metric index patterned after the original described by Karr (1981). The metric scoring range is from one to five, where one, three, or five are the only metric scores possible. The higher metric score is considered more favorable. The sum of the metrics becomes the IBI score, and the maximum possible is 60. The twelve IBI metrics for headwater sites

(<20 square mile drainage areas) are listed below:

- Total Number of Indigenous Fish Species
- Number of Darter Species
- Number of Headwater Species
- Number of Minnow Species
- Number of Sensitive Species
- Percent Abundance of Tolerant Species
- Percent Omnivores
- Proportion as Insectivores
- Proportion of Pioneering Species
- Relative Number of Individuals
- Number of Simple Lithophils
- Percent DELT Anomalies on all Species

The sites were compared to Warmwater Habitat (WWH) criteria by compiling and interpreting the values of the IBI score. Streams attaining the WWH criteria meet standards set by the Water Quality Act of 1987 and have achieved the “fishable / swimmable” goals set by that act. Scores above 36 are considered to meet WWH criteria, and are expected to support healthy, reproducing fish communities. The numeric IBI values were used to narratively classify sites as representative of “exceptional” (IBI scores between 50 to 60) , “very good” (46-49), “good” (40-45), “marginally good” (36-39), “fair” (28-35), “poor” (18-27), or “very poor” (12-17) fish community condition. These narrative ranges were derived by the OEPA for streams similar to Hardy Lake tributaries within the Interior Plateau Ecoregion. Field data sheets can be found in Appendix B, and IBI score sheets can be found in Appendix C.

2.1.3 Benthic Macroinvertebrates

Benthic macroinvertebrates were collected twice during the 1999 field season using qualitative methods. Although sampling sites were the same, sampling methods differed between sampling events.

Benthic macroinvertebrates were collected from five sites in March, 1999 using the Multihabitat approach as outlined in the Federal Rapid Bioassessment Protocols (RBPs). At each site, macroinvertebrates were collected from all major habitats within a 100 m reach using a D-framed dip net. This reach coincided with the fish sampling reach. Major habitats included riffle/runs, woody debris snags, undercut banks, root wads, in-stream vegetation, leaf packs and depositional zones. A total of 20 jab/kicks were obtained in the reach and were composited into one sample for processing. The number of jabs or kicks taken in each habitat was in proportion to the percentage of each habitat type within the sampling reach. For example, if the riffle/run habitat comprised 30% of the reach, then a total of six jab/kicks were obtained in that habitat. Jabs were obtained by jabbing a D-framed net into the sampling zone (e.g., root wads, leaf packs, debris dams), scraping the substrate and sweeping in a uniform motion until the net was out of the water. Kick sampling was performed by placing the net in a stationary position facing upstream and disturbing the substrate immediately upstream of the net.

Invertebrates were picked from the sample in the field and placed in a sample container with buffered 7-8% formalin as a preservative. All samples were labeled in the field at the time of collection. Sample labels were written with a lead based soft pencil or water resistant ink and placed inside the sample container. The outside of each container was labeled with the same information. After returning to the laboratory, each sample was assigned a unique sequential identification (ID) number. This number identified the sample in a permanent ledger where the information from the chain of custody form was recorded. A copy of the chain of custody form was retained for permanent record. The chain of custody form, the sample ID number, and the ledger documented the transfer of the sample from the field to the laboratory. The sample ID number was placed on and in each sample container, and also on all specimen vials and microscope slides. Samples were then taken to EnviroScience's macroinvertebrate lab for sorting and identification.

Organisms were identified to the lowest practical taxonomic level (generally genus/species). When necessary, identified specimens were compared to EnviroScience's permanent reference collection for confirmation. The reference collection consists of organisms that have been verified by an outside authority in macroinvertebrate identification. A supervising biologist performed initial confirmation of macroinvertebrate identifications. A voucher collection of all representative species collected during this study is permanently housed in the Department of Entomology, Purdue University.

When the number of individuals from a taxonomic group was estimated to exceed a minimum standard required for initiation of subsampling techniques (70 EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa, 100 all other groups), organisms were subsampled prior to identification. Subsampling was completed by random extraction of organisms from the sample until adequate numbers were counted. Remaining organisms were extrapolated and recorded to obtain relative numbers for the sample.

Prior to identification, members of the Dipteran family Chironomidae (midges) were cleared by being mounted on a microscope slide in CMC-9 (Masters Company, Inc.) and allowed to dry.
As organisms were being identified and counted, this information was recorded on Aquatic Invertebrate Bench Sheets (Appendix D), and on labels inserted in the sample vials

Unlike the fish community analysis, the macroinvertebrate data was evaluated using a number of indices each describing a different characteristic of the community. Data analysis was based on the following seven metrics from Klemm et al. (1990), each of which examined a slightly different aspect of the invertebrate community:

- Taxa richness
- Number of EPT taxa

- The percent dominant taxa
- Equitability Index
- Ratio of Scrapers/Filterers
- The percent contribution of Shredders
- The Hilsenhoff Biotic Index

A rapid assessment of stream health can be estimated simply by determining taxa richness, which is generally considered to increase with increasing water quality, habitat diversity and habitat quality.

The EPT metric analyzes the number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in the community. These taxa are generally considered to be intolerant of pollution with stoneflies being the least tolerant. It should be noted that taxa considered tolerant are widespread and can be found in all types of habitat and ranges of water quality, where as intolerant species tend to be restricted to good to excellent water quality.

The percent dominant taxon metric is a simple measure of the community balance among the species. In good water quality, species should be distributed relatively even throughout the community. A community dominated numerically by one or a few species is indicative of environmental stress, and tolerant organisms can become dominant at disturbed site, particularly in areas of organic pollution (Ohio EPA 1987).

The equitability index is a more quantitative calculation of community balance by accounting for both diversity and abundances among the species. This value is calculated as the Shannon-Wiener Index (H') divided by the theoretical maximum Shannon-Wiener Index value (H), which are calculated by the following formulas:

H':$\Sigma((n_i/N)*(\log 10\ (n_i/N)))$, where n_i= the number of individuals in the ith species, and N= the number of individuals in the sample.

H: log10 (1/N)

The more evenly distributed species are in the community, the closer the equitability index will be to 1.0. Also, water quality is considered better the closer the value is to 1.0. Values above 0.5 are found in areas not affected by organic enrichment, and values below 0.5 are evidence of slight degradation.

Analyzing the functional feeding groups (FFG) within the invertebrate community provides an indication of community dynamics, and can be used to detect potential disturbances in the system. The predominance of one FFG may be an indication of an unbalanced community responding to an abundant food source. Scrapers, piercers and shredders are considered specialized feeders and are generally considered sensitive to disturbances. They are typically well-represented in healthy streams. Generalists, such as collectors and filterers are more tolerant to degradation because of their flexibility with regard to acceptable food resources. The ratio of scrapers to filterers gives an indication of what is occurring within the riffle/run community. Scrapers increase when periphyton is abundant, and decrease when filamentous algae and aquatic mosses become abundant. Filterers feed on fine particulate organic matter (FPOM) and are predominant when filamentous algae is overabundant. Both FPOM and an overabundance of filamentous algae tend to dominate in areas of organic enrichment.

Shredders are good indicators of riparian zone impacts since they feed primarily on course particulate organic matter (CPOM) (i.e. leaves) that originate out of the stream. Shredders are also good indicators of toxicity from pollutants that may be bound to CPOM.

The Hilsenhoff Biotic Index (HBI) was developed to detect organic pollution, and has been successfully tested in several states throughout the Midwest. The HBI summarizes the invertebrate community into a single numerical value which is then compared to a rating scale. Values range from zero to ten, with narrative ranges given as:

- 0.00-3.55 Excellent, no apparent organic pollution
- 3.51-4.50 Very Good, possible slight organic pollution
- 4.51-5.50 Good, some organic pollution
- 5.51-6.50 Fair, fairly significant organic pollution
- 6.51-7.50 Fairly Poor, significant organic pollution
- 7.51-8.50 Poor, very significant organic pollution
- 8.51-10.00 Very Poor, severe organic pollution

Macroinvertebrate samples were collected on October 23rd, 1999 at the same stream reaches sampled in March, 1999. These samples were analyzed using BIORECON (Barbour et al. 1997) methodology. The BIORECON is a faster and more qualitative approach than the Multihabitat methods, however the BIORECON approach has limited interpretation value if used alone. It is considered one of the least rigorous invertebrate sampling methods, and has traditionally been used to identify potential problem areas prior to more comprehensive studies. For this study, the BIORECON approach was used as a cost-effective method to determine if major shifts in the macroinvertebrate community occurred between spring and fall sampling. The methods used for BIORECON sampling and processing were similar to that of Multihabitat sampling except only one to two jab/kicks were obtained in each habitat, and specimens were only identified down to the family level. Also, once organisms were identified they were recorded on a Preliminary Assessment Score Sheet (PASS) instead of EnviroScience's bench sheets.

The BIORECON approach requires specific target thresholds to be established at each site prior to sampling (see PASS sheet, Appendix E). Based on the data from the spring samples, three target thresholds were established. These were the overall number of taxa, the number of EPT taxa, and a tolerance index. Because family level identifications were used for the fall BioRecon survey, the thresholds established for the number of taxa and EPT taxa equaled the number of families obtained from the spring samples. The tolerance index threshold used was the HBI calculated from the spring samples. It should be noted the HBI was calculated from identifications down to the species level, but the Hilsenhoff Family Biotic Index (FBI) used in this analysis, which is a modification of the HBI, is calculated from family-level identifications. However, they are both rated on the same scale, with lower values indicating better water quality. Also, a narrative score is associated with the numerical value (i.e. excellent, good, fair, poor). The basis for whether a site met or exceeded the tolerance index threshold was on the narrative score rather than the numerical score.

At the time of fall sampling, the Site 5 stream reach contained no water, and therefore no fall sample was obtained.

2.2 Stream Water Quality

2.2.1 In-field and Analytical Chemistry Sampling

EnviroScience monitored select tributary streams to Hardy Lake for in-field and analytical chemistry, and turbidity. The results from each analysis were compared with average water quality values as determined by the IDNR (Table 2-1). Sampling sites were selected to represent water quality entering the lake, and are identified as Sites 1 to 8 (Figure 2-1). In-field and analytical chemistry were analyzed at all sites (Appendix F). Turbidity was measured at Sites 1, 3, 4, 5, and 8. Sampling events occurred between May and October, 1999, and rainfall data was included for each event. No analytical chemistry was collected after a significant storm event.

In-field chemistry was analyzed for four parameters using a Hydrolab Reporter™ connected to a Hydrolab Scout® 2 display unit. The Hydrolab was calibrated prior to each workday. Sample parameters included dissolved oxygen, pH, conductivity, and temperature. In-field chemistry was acquired by collecting a water sample using a stainless steel bucket and then lowering the Hydrolab into the sample. Readings were recorded once the display unit values stabilized. Prior to collection the stainless steel bucket was carefully rinsed with water from the sample site.

Analytical chemistry sampling was performed for five parameters at each stream site on May 18th and October 28th, 1999. These parameters included total phosphorus, nitrate/nitrite, ammonia, total kjedahl nitrogen (TKN), and total suspended solids (TSS). The analysis for the May 18th sampling event was performed by Environmental Control Laboratories and the October 28th event was performed by American Testing Company, Inc. The method numbers and detection limits are presented in Appendix F. Water samples were collected using a stainless steel bucket and then transferred to sample bottles provided by the analytical laboratory. The transfer between the field and analytical lab was documented on Chain of Custody Forms (Appendix G).

Table 2-1. Range and average of Indiana water quality parameters

Parameter	Range	Average
Dissolved Oxygen (mg/L)	5.4-14.8	9.2
pH	6.6-8.3	7.5
Conductivity (umhos)	466-709	587
Nitrate/Nitrite (mg/L)	0.9-3.15	2.05
TKN (mg/L)	0.63-1.67	1.15
Total Phosphorus (mg/L)	0.01-0.17	0.09
Ammonia (mg/L)	0.02-0.46	0.24

2.2.2 Turbidity and Stream Flow

EnviroScience personnel and the Hardy Lake Manager monitored five stream sites (1, 3, 4, 5, and 8) for turbidity using a turbidity stick. Turbidity was analyzed on seven events between May 18th and October 11, 1999. An effort was made to analyze turbidity during the first flush after substantial rain events. However, drought conditions made this problematic with very few rain events between sampling dates. The turbidity stick consisted of a hollow tube of plexiglass approximately 1 inch in diameter and 36 inches long having a small secchi disk at one end. Turbidity was measured by filling the stick with a sample and gradually letting water out until the Secchi disk was just visible at the bottom of the tube. The water level in the tube was then recorded. The readings were compared to readings recorded during periods of no rainfall.

After collecting turbidity data at Sites 1, 3, 4, and 5, stream discharge was measured. Discharge was determined by measuring the water level from the top of a pre-calibrated structure such as a culvert, bridge pier, or metal fence post. The water depth was calculated by subtracting the water level from the measurement of the structure to the substrate.

2.3 Lake Water Quality

2.3.1 Deep Hole Monitoring

The deep hole of a lake is defined as the deepest point of water depth. The Hardy Lake deep hole is located in the northwest portion of the lake (Figure 2-2) and is approximately 36 feet deep. A deep hole sample was collected twice during the 1999 sampling season, July 7 and October 28 (Appendix F). Deep hole sampling was conducted to calculate the IDEM Eutrophication Index for Hardy Lake. The IDEM Eutrophication Index was created for use in Indiana to evaluate eutrophication by measuring several chemical and physical parameters in a lake. The following parameters were sampled to calculate the IDEM Eutrophication Index for Hardy Lake in 1999:

- Total Phosphorus (ppm)
- Soluble Reactive Phosphorus (SRP; ppm)
- Organic Nitrogen (ppm)
- Nitrate (ppm)
- Ammonia (ppm)
- Dissolved Oxygen (percent saturation 5 feet from surface)
- Dissolved Oxygen (percent of water column with >0.1ppm dissolved oxygen)
- Light Penetration (Secchi Disk)
- Light Transmission (% at 3' depth, estimate based on Secchi Disk transparency)
- Total Plankton (between 1% light penetration and the surface)

Water samples were collected with a two-liter Kemmerer bottle at the bottom mid-depth and surface of the lake. These samples were then composited and transferred to sample bottles provided by Environmental Control Laboratories. Secchi Disk readings were taken between the hours of 09:00 and 15:00 on each sampling day.

Figure 2-2. Lake survey sample sites

2.3.2 Analytical Chemistry Sampling Sites

EnviroScience sampled five sites within Hardy Lake to generate a representative profile of the water quality. The one time sampling event was completed on May 17th, 1999. Two parameters chlorophyll *a* and total phosphorus were collected and transferred to Environmental Control Laboratories for analysis. Samples were collected at mid-depth using a two-liter Kemmerer bottle and were transferred to pre-cleaned analytical sample bottle. In-field chemistry including dissolved oxygen, pH, water temperature and specific conductance were completed at each site.

2.3.3 Aquatic Plant Survey

EnviroScience completed a qualitative survey of aquatic plants in Hardy Lake in July of 1999. The entire shoreline of Hardy Lake was evaluated and sampled from the water by experienced biologists (Figure 2-2). The survey focused on and identifying any potential problem areas and developing an aquatic plant species list. Each species of plant encountered during the survey was collected and placed on ice in bags and transported to EnviroScience for laboratory examination. Significant beds of aquatic plants were marked with GPS for the development of detailed maps. Furthermore at each GPS location field notes were taken describing any pertinent information such as species present, density, dimensions of plant beds, and shoreline communities to aid map development. Particular attention was given to non-native species, including emergents such as purple loosestrife which inhabit lake margins. At several sites around the lake, plant samples were collected using a rake tow to accurately assess plant community structure in the area. The samples were placed in bags on ice and transported back to EnviroScience for detailed examination and to confirm field identification. Each plant was identified given a qualitative percent abundance.

2.4 Secondary Source Review

Secondary sources of information such as academic libraries and government agencies were reviewed for natural resource information specific to Hardy lake and its watershed. This information was jointly compiled by the Jefferson County SWCD and EnviroScience. The SWCDs had the primary responsibility for compiling this material and supplying copies of it to EnviroScience. Once received, the relevant information was summarized and incorporated into data files used for the GIS database for Hardy Lake. Existing secondary sources examined included, but were not limited to:

- USGS topographic maps
- USGS Water Resources Data for Indiana
- USEPA National Eutrophication Survey
- US Fish and Wildlife Service National Wetland Inventory maps
- USDA Natural Resource Conservation Service maps and publications
- National Oceanic and Atmospheric Association studies and reports
- Indiana Department of Environmental Management (IDEM) Comprehensive Water Quality Reports
- IDNR Division of Nature Preserves Natural Heritage Program database on rare, threatened, and endangered species
- IDNR Fish Management Reports
- Indiana Lake Classification Surveys
- Indiana Geological Survey maps and publications
- Indiana State Museum Records
- Jefferson and Scott County SWCD studies, reports, including soil surveys
- Reports and studies from local colleges and universities
- Aerial photographs of the site
- Other relevant reports and documents from the county, state, or federal government

2.5 Land Use Analysis

The Hardy Lake drainage consists of 13 subwatersheds as delineated by EnviroScience. One subwatershed (the Quick Creek headwaters) was divided into two subwatersheds because of its large size and the project sampling design. Subwatersheds were defined as a drainage that entered directly into the lake. The near-shore watershed consisted of areas of surface water runoff having little or no channelization.

The Hardy Lake watershed and sub-watershed research was completed using a combination of private and public information sources, as well as on-site field verifications by EnviroScience. These sources included USGS Digital Orthometric Quadrangle (DOQ) image files, USGS Topographical maps, National Wetlands Inventory Maps (NWI), the Federal EPA's on-line land use model L-THIA (http://danpatch.ecn.purdue.edu/-sprawl/LTHIA2), soil survey maps, and Important Farmland County maps. These information sources were then combined as layers in a GIS-based model of the Hardy Lake watershed to facilitate the study and comparisons of each study parameter.

Runoff data was calculated following the long-term hydrological impact assessment model (L-THIA; Appendix I) as developed by the EPA in cooperation with Purdue University. The L-THIA is a tool that evaluates the effects of land use change on hydrology and non-point source pollution. This model combined soil type, area of land, precipitation, land-use to calculate the average annual runoff volume (acre-ft) of water per subwatershed, and the average annual runoff depth (inches). This data can be used to assess the relative amount of runoff entering Hardy Lake and its tributaries, and identify areas possibly contributing non-point source pollution.
EnviroScience combined all relevant and available data into a GIS database of Hardy Lake and its watershed. The ultimate goal of the GIS was to improve the lake and land manager's ability to diagnose problem areas, document changes, as well as set the framework for future management.

The work on the DOQ base map used to create the Hardy Lake watershed land use map was accomplished in AutoCAD R14. The base map was supplied by the USGS and consisted of four Digital Orthophoto Quadrangle (DOQ) files in GeoTIFF format. The projection was Universal Transverse Mercator (UTM), Datum NAD83, with a resolution of 1.0 meter pixels. A DOQ is an aerial photograph that has been computer corrected for optical distortion (fisheye effect) caused by the camera lens and saved in a computer file format. After correction, this image can be viewed by various computer programs such as ArcView or ArcInfo. Various other layers were then aligned with the base map in AutoCAD, such as USGS topographic and NWI maps. Because some of these maps are in a projection other than UTM, some layers of the GIS do not align exactly.

The GeoTIFF DOQ base map was used to investigate land uses within the Hardy Lake watershed. Land uses could be identified fairly accurately due to the extremely high resolution of the DOQ. For example, row crops could be differentiated from untilled fields or old field areas. However, pasture/old field land was difficult to identify, and required field verification. A percentage of the land use designations were then field verified for quality assurance purposes. USGS 7.5 minute topographic maps were used to define the subwatersheds and tributaries of Hardy Lake. Field Global Positioning System (GPS) points provided the exact locations of the various biological sample sites, aquatic plant surveys, and lake chemistry sites. Additional secondary source material such as National Wetland Inventory (NWI) Maps were also added. Some secondary source information was not available as of the release of this report, (such as electronic soil survey maps), but can be added as the information becomes available.

Land use within the Hardy Lake watershed was placed into four categories based on DOQs and field observations. Along with watered areas and wetlands, these included:

- FOREST - an area with predominately woody cover (some successional areas also)
- PASTURE / OLD FIELD- non-tilled land, old field
- AGRICULTURE - tilled cropland

- RESIDENTIAL - areas of private residences and closely mowed edges
- WATER - lakes, ponds, Hardy Lake
- WETLAND - any area of wetland as defined in the National Wetlands Inventory

Wetland definitions overlap other land use designations. This is because an area can be used as residential, farmland, etc. and still be defined as a wetland by the NWI map.

3.0 Results and Discussion

Within the Hardy Lake watershed area, subwatersheds and land-uses were identified and their borders delineated. Habitat and biological community data, in-field chemistry, and analytical chemistry were collected from tributaries of select subwatersheds. The following discussion describes each subwatershed separately. In-field chemistry, analytical chemistry, and a aquatic plant survey were performed at selected sites in Hardy Lake.

Eight sites within the Hardy Lake watershed were chosen for habitat, biological communities, and chemistry surveys (Figure 2-1). These were labeled in the field as sites one through eight, and were reported as so on all field data sheets (see Appendices). However, for this report, all data will be identified and discussed in relation to the subwatershed where each site was located, which are as follows:

· Site 1 - Subwatershed 3
· Site 2 - Hardy Lake Outlet Stream
· Site 3 - Subwatershed 4
· Site 4 - Subwatershed 5
· Site 5 - Subwatershed 8
· Site 6 - Subwatershed 9
· Site 7 - Subwatershed 10

· Site 8 - Subwatershed 1

3.1 Subwatershed and Stream Survey Parameters

3.1.1 Land-use

Four land uses were identified within the overall Hardy Lake watershed using aerial photographs and field verifications (Table 3-1). These included forest, pasture/old-field, residential and agricultural. Wetland areas were included under forest or pasture/old-field depending on the surrounding land-use. Watered areas included ponds, channels, and streams, but excluded Hardy Lake.

Agricultural land was the most predominant land use within the Hardy Lake watershed encompassing 50.3% of the land (3,371.9 acres, 1,364.6 hectares). Forests also comprised a significant proportion of the watershed encompassing 36.2% of the land (2,428.8 acres, 982.9 hectares). Approximately 2.6% of the land was in wetlands (175 acres, 70.8 hectares), and were primarily located at confluences of the tributary streams with the lake.

Table 3-1 Predominant land-uses within the Hardy Lake watershed

Land-use	Acres	Hectares	% of Hardy Lake Watershed
Forest	2,428.8	982.9	36.2
Pasture/old-field	346.2	140.1	5.2
Agriculture	3,371.9	1,364.6	50.3
Residential	535.7	216.8	7.9
Water	25.2	10.2	0.4
Total	**6707.8**	**2,714.6**	**100.0**
Wetland	174.9	70.8	2.6

In evaluating the health of a watershed, it's important to consider the various land uses. Agricultural lands are traditionally considered to have the greatest impact on biological, chemical, and geological process occurring within the watershed. The quantity of run-off reaching streams and/or lakes will depend greatly on the agricultural methods being used (i.e. the type of crop, tillage practices, etc.). This is important because run-off can significantly affect erosional processes, and can carry excess sediment, organic wastes and/or pesticides into adjacent water bodies. The presence of buffer strips will reduce the extent of run-off, as will wetlands (see section 3.2.15, "Areas of Concern"). Forested land and pasture/old-field are two important land uses that can serve as buffer strips when they are located adjacent to the stream. However, if pasture land is predominantly used to raise farm animals, then its function as a buffer strip can be seriously compromised because run-off can carry excess concentrations of organic waste into the water body. Once in the water body, sediment, organic waste and chemicals will disrupt physical characteristics of the water body and the resident biological communities.

3.1.2 Subwatersheds

Thirteen subwatersheds were identified within the Hardy Lake watershed area (Table 3-2, Figure 2-1) covering 6,707.8 acres (2,714.6 hectares) of land. An area was identified as a subwatershed based on topography and the presence of tributaries. The shoreline area immediately adjacent to Hardy Lake was considered a separate subwatershed because run-off drained directly into the lake.

Subwatershed 4 in the southeast portion of the Hardy Lake watershed covered the largest area (1,699.9 acres, 687.9 hectares; Figure 2-1), encompassing 25.4% of the area. The shoreline also covered a significant area of land (1,395.5 acres, 564.7 hectares) enclosing 20.8% of the watershed. Subwatershed 6 was the smallest subwatershed identified covering only 1.1% of the area (74.5 acres, 30.1 hectares).

The size of a watershed has obvious importance when evaluating its potential impact to the water body. Watersheds encompassing larger areas will have a greater potential to provide more runoff, depending on land use.

3.1.3 Runoff Results

Runoff estimates were calculated following the USEPA's L-THIA model. This model combined soil type, land area, precipitation, and land-use to calculate the average annual runoff volume of water draining each subwatershed, and the average annual surface runoff depth (inches per acre; Table 3-3). Results of the runoff volume calculation are given in units of acre-ft, which is equivalent to the volume of the number of acres of water one foot deep that runs off a subwatershed.

Table 3-2. Subwatershed areas within the Hardy Lake watershed

Subwatershed	Acres	Hectares	% of Hardy Lake Watershed
Subwatershed 1	623.5	252.3	9.3
Subwatershed 2	499.3	202.1	7.4
Subwatershed 3	682.3	276.3	10.2
Subwatershed 4	1,699.9	687.8	25.4
Subwatershed 5	692.2	280.1	10.3
Subwatershed 6	74.5	30.1	1.1
Subwatershed 7	108.4	43.9	1.6
Subwatershed 8	255.5	103.5	3.8
Subwatershed 9	265.4	107.5	4.0
Subwatershed 10	117.4	47.5	1.7
Subwatershed 11	173.5	70.1	2.6
Subwatershed 12	120.4	48.7	1.8
Subwatershed 13- Shoreline	1,395.5	564.7	20.8
Total	**6,707.8**	**2,714.6**	**100.0**

Table 3-3. L-THIA values for each subwatershed

Subwatershed	Acres	% AG	% For	Runoff Volume (acre-ft)	Runoff Depth (inches)
Subwatershed 1	623.5	48.3	39.3	190.5	3.7
Subwatershed 2	499.3	45.0	46.0	133.2	3.2
Subwatershed 3	682.3	55.1	34.9	197.0	3.5
Subwatershed 4	1,699.9	68.3	18.4	621.7	4.4
Subwatershed 5	692.2	62.3	30.5	215.3	3.7
Subwatershed 6	74.5	67.1	21.9	20.6	3.3
Subwatershed 7	108.4	51.0	41.5	25.4	2.8
Subwatershed 8	255.5	45.3	32.8	71.0	3.3
Subwatershed 9	265.4	40.5	47.7	66.6	3.0
Subwatershed 10	117.4	25.5	35.8	23.8	2.4
Subwatershed 11	173.5	40.2	55.2	35.0	2.4
Subwatershed 12	120.4	70.1	18.5	43.6	4.3
Subwatershed 13- Shoreline	1,395.5	26.2	54.4	212.1	2.7
Total	**6,707.8**			**1,855.8**	**--**

Subwatersheds with larger annual runoff volumes will ultimately provide higher volumes of water to Hardy Lake. Subwatersheds with higher runoff depths will likely have more torrential runoff, and subsequently have more erosion potential. Runoff will naturally carry sediment, organic waste and/or pesticides to the stream or lake, but higher volumes and depth of runoff have the ability to carry more.

Runoff is dependent on the size of the watershed, the surrounding land use and soil characteristics (i.e. its ability to absorb water). For this study, subwatersheds with a greater proportion of agricultural land had a greater average annual runoff, and those with a greater

proportion of forested land had smaller runoff. Runoff volumes generally increased as watershed size increased (Figure 3-0).

Approximately 1, 856 acre-feet of average annual runoff volume was entering the Hardy Lake watershed per year. Subwatershed 4 had the highest runoff volume at 621.7 acre-feet per year. Subwatersheds 1, 3, 5 and 13 were all approximately 200 acre-feet per year. Even though the shoreline area comprised the second largest area of land, it had a relatively low runoff volume. This is most likely due to the large amount of forested land covering this subwatershed, particularly in near-shore areas. Subwatershed 6 had the smallest yearly runoff volume at 20.6 acre-feet per year. However, this subwatershed did not have the smallest average annual runoff depth per acre. Subwatersheds 10 and 11 had the lowest average runoff depth per year, both providing 2.4 inches. Subwatersheds 4 and 12 had the greatest average runoff depth per year with values of 4.4 and 4.3 inches, respectively. A discussion of runoff values that were considered important (Subwatersheds 1, 3, 4, 5, 12) are included under their respective subwatershed description.

Figure 3-0. The relationship between runoff volume and percent watershed area.

3.1.4 Habitat Results

The available habitat within a stream is one of the main factors regulating what biological communities can inhabit the area. The habitat survey evaluated the quantity and quality of available in-stream habitat, as well as riparian zone characteristics that affect in-stream habitat. The metrics used to evaluate habitat summarize four main components important to the biological communities. These include the degree of available instream cover, sedimentation and erosion, physical attributes of the stream that govern water flow, and the quality of the riparian zone. The available instream cover refers to the types of substrates available for refuge, feeding, spawning and reproduction by the fish and macroinvertebrate communities. In-stream habitat data was collected from the four main tributaries to Hardy Lake (Subwatersheds 3, 4, 5, and 8), and from the outfall stream (Table 3-4). The results and discussion of each sample site can be found under each subwatershed description. Overall, four sites were considered to have sub-optimal habitat. The tributary draining Subwatershed 5 was considered to have only marginal habitat. Consistent problems among all sites related to metrics evaluating the quantity and quality of available instream cover (metrics 1, 2 and 5), and sedimentation factors (metrics 4 and 8; see section 3.2.15, "Areas of Concern").

3.1.5 Biological Results

Biological samples were collected from the four main tributaries to Hardy Lake (Subwatersheds 3, 4, 5, and 8), and from the outfall stream. A fish community analysis was performed in March 1999, and benthic macroinvertebrate data were collected in March and October 1999. Macroinvertebrates were not collected from Subwatershed 8 in October because the stream channel was dry. The results and discussion of each sample site can be found under each subwatershed description. No threatened or endangered species were encountered during the completion of this study.

Table 3-4. Hardy Lake Watershed Habitat Evaluation Metric Scores

	Subwatershed				
Metric	**3**	**4**	**5**	**8**	**Outfall**
1. Epifaunal Substrate/ Available Instream Cover	9	8	9	12	11
2. Pool Substrate Characterization	11	10	13	11	12
3. Pool Variability	13	17	8	7	13
4. Sediment Deposition	10	8	8	9	8
5. Channel Flow Status	13	9	7	12	17
6. Channel Alteration	18	20	8	20	15
7. Channel Sinuosity	12	16	3	19	8
8. Bank Stability	14	8	8	13	18
9. Vegetative Protection	18	20	14	12	20
10. Riparian Vegetative Zone	16	20	13	20	15
Total	**134**	**136**	**91**	**135**	**137**

3.1.5.1. Fish Results

For the overall study, the fish community in Subwatershed 5 is considered "very good", as indicated by the highest IBI score attained of 46 (Table 3-5). Subwatersheds 3 and 8, and the outfall site all achieved narrative scores of "good". Subwatershed 4 had the lowest IBI score of 38 resulting in a narrative score of “marginally good”. However, all sites are considered to be in attainment of WWH criteria (scores $\geq$ 36) for fish populations. Only one metric was consistently considered poor among all sample sites, the number of headwater species (metric 3).

Table 3-5 Fish IBI scores from sample sites within the Hardy Lake watershed

	Subwatershed				
Metric	**3**	**4**	**5**	**8**	**Outfall**
1. Total Number of Indigenous Species	5	5	3	3	5
2. Number of Darter Species	3	3	5	3	1
3. Number of Headwater Species	1	1	1	1	1
4. Number of Minnow Species	3	3	3	3	3
5. Number of Sensitive Species	3	5	3	3	3
6. Percent Abundance of Tolerant Species	3	1	5	5	5
7. Proportion as Omnivores	1	1	5	3	5
8. Proportions as Insectivores	5	3	5	5	5
9. Proportion of Pioneering Species	3	1	5	5	5
10. Number of Individuals	5	5	5	3	3
11. Number of Simple Lithophils	3	5	1	1	3

12. Percent of DELT Anomalies	5	5	5	5	3
Total	**40**	**38**	**46**	**40**	**42**

Nineteen fish species were collected from tributaries in the Hardy Lake watershed (Table 3-6). The differences in IBI metric scores relates to the fish species present at each site. Certain fish species are indicative of good water quality while others are characteristic of degraded water quality.

Metric 3 measures the presence of headwaters species. These species need permanent habitat which is typically water availability coupled with minimum environmental stressors. All sample sites received a score of one due to the complete absence of headwater species. This score can most likely be attributed to the natural distribution of these species. According to the Indiana Department of Environmental Management (IDEM), there are relatively few headwater species found in the Hardy Lake region.

Metric 5 measures the presence of sensitive species. All sample tributaries received a score of three except subwatershed 4 which scored a five. Three sensitive intolerant species were collected and include the silver shiner (*Notropis photogenis*), bigeye shiner (*Notropis boops*), and rainbow darter (*Etheostoma caeruleum*).

Metric 6 measures the percent abundance of tolerant species, and is specifically designed to indicate a change from fair to poor water quality based on the percentage of tolerant fish. Subwatershed 4 received a low score of one due to a high proportion of bluntnose minnows (*Pimephales notatus*, 80%). Subwatershed 3 received a score of three from the presence of 50% tolerant fish within the population. The remaining sampling locations had tolerant fish composing 25% or less of their respective populations. The scores of subwatersheds 3 and 4 would seem to indicate an environmental stressor affecting the biology of the streams.

Metric 7 measures the proportion of omnivores inhabiting a sample location. A high percentage of omnivores typically indicates a disruption in the food base because these species can adjust

Table 3-6. Fish species collected from tributaries in the Hardy Lake watershed

Common Name	**Genus Species**
smallmouth buffalo	*Ictiobus bubalus*
white sucker	*Catostomus commersoni*
northern creek chub	*Semotilus atromaculatus*
suckermouth minnow	*Phenacobius mirabilis*
silver shiner	*Notropis photogenis*
central striped shiner	*Notropis chrysocephalus*
bigeye shiner	*Notropis boops*
spotfin shiner	*Notropis spilopterus*
bluntnose minnow	*Pimephales notatus*
Ohio stoneroller	*Campostoma anomalum anomalum*
blackstripe topminnow	*Fundulus notatus*
northern rock bass	*Ambloplites rupestris*
largemouth blackbass	*Micropterus salmoides*
warmouth	*Lepomis gulosus*
green sunfish	*Lepomis cyanellus*
northern bluegill sunfish	*Lepomis macrochirus*

central longear sunfish	*Lepomis megalotis*
johnny darter	*Etheostoma nigrum*
rainbow darter	*Etheostoma caeruleum*

diet freely. In disrupted or unbalanced habitats, omnivores can quickly become the dominant species. Two omnivore species were collected and include the white sucker (*Catostomus commersoni*) and bluntnose minnow. Subwatersheds 3 and 4 received a score of one, and the remaining sites received a score of five because of the absence or minimal population omnivore species.

Metric 8 examines the proportion of pioneering species which is also a metric designed to distinguish temporary habitat. A total of four pioneering species were collected and include the johnny darter (*Etheostoma nigrum*), northern creek chub (*Semotilus atromaculatus*), green sunfish (*Lepomis cyanellus*) and bluntnose minnow. Subwatershed 4 had the highest percentage (80%) of pioneering species due to the large number of bluntnose minnows. Subwatershed 3 contained a high number of pioneering species (48.8%) primarily northern creek chub. The remaining subwatersheds received higher IBI scores because of the relatively small number of pioneering fish sampled.

Metric 11 evaluates stream habitat quality based on the number of simple lithophilic spawners. Lithophilic spawners require gravel and/or cobble type habitat for reproduction. This type of breeding was found to be most sensitive to habitat loss or degradation due to silt or sediment loads. A total of six lithophilic spawners were collected and included the suckermouth minnow (*Phenacobius mirabilis*), central striped shiner (*Notropis chrysocephalus*), silver shiner, bigeye shiner, white sucker and rainbow darter. Subwatershed 5 and 8 both received a score of one because only one species, the rainbow darter, was present. The other sample locations scored higher due to the presence of at least two or more lithophilic spawners.

3.1.5.2. Benthic Macroinvertebrate Results

For the overall study, the March macroinvertebrate data (Table 3-7) indicate these study streams are relatively healthy, but are experiencing some degree of perturbation (see section 3.2, "Subwatershed Descriptions"). The October macroinvertebrate data evaluation was based on the data collected in March through the establishment of target thresholds (Table 3-8). If two of the three target thresholds were not met, then the community was considered to have undergone a significant change from the spring data (see Section 2.1.3, "Benthic Macroinvertebrate" methods). A list of species collected at each site during each season can be found in Table 3-8a.

Because the macroinvertebrate community was assessed using qualitative methods, the data could not be reduced to one number describing the community, unlike the fish data. Therefore, a number of indices were chosen that evaluate different components of the macroinvertebrate assemblage. Problems common to all sample sites were related to the percentage of shredders and the HBI scores (see section 3.2.15, "Areas of Concern").

Table 3-7. Benthic macroinvertebrate data collected within the Hardy Lake watershed (March 1999)

	Subwatershed				
Metric	**3**	**4**	**5**	**8**	**Outfall**
Taxa Richness	41	24	19	20	19
No. of individuals	209	131	197	445	100
No. of EPT taxa	11	9	7	5	3
% Dominant taxa	0.254	0.41	0.33	0.535	0.23
Dominant taxa	*Lirceus* sp.	*Lirceus* sp.	*Lirceus* sp.	*Lirceus* sp.	*Cheumatopsyche* sp.
Equitability Index	0.56	0.48	0.41	0.20	0.57
Ratio of Scrapers to Filterers	1.04	23.0	2.69	No filterers collected	0.29
% Shredders	0.029	0.038	0.066	0.002	0.0
HBI	5.56	6.86	6.08	7.72	5.98

Table 3-8. Benthic macroinvertebrate data collected within the Hardy Lake watershed (October 1999)

	Subwatershed				
Metric	**3**	**4**	**5**	**8**	**Outfall**
No. of taxa	21	13	13	No flow	13
Target Threshold	22	20	16	18	10
No. EPT taxa	9	4	6	No flow	5
Target Threshold	9	8	6	5	2
FBI	4.98	4.82	3.35	No flow	6.00
Target Threshold	5.56	6.86	6.08	7.72	5.98

Table 3-8a. Macroinvertebrate species collected from tributaries in the Hardy Lake watershed

(S=Spring, F= Fall, * organisms collected in fall only identified to family)

Class/Order	Family	Species	Subwatershed				
			3	4	5	8	Outfall
			S / F	S / F*	S / F*	S / F*	S / F*
Turbellaria	Planariidae					2 / -	
Oligochaeta			1 / -	4 / -		4 / -	2 / 2
Isopoda	Asellidae	*Lirceus* sp.	53 / 22	54 / 2	65 / 2	238	4 / -
Amphipoda	Crangonyctidae	*Crangonyx* sp.	- / 5	16 / -	17 / 5	161 / -	11 / 1
	Taltridae	*Hyalella azteca*					- / 4
Decapoda	Cambaridae	*Orconectes obscurus*		- / 1	1 / 5	1 / -	
	Cambaridae	*Orconectes virilis*		1 / -			
Gastropoda	Lymnaeidae		- / 2				
	Physidae	*Physella* sp.	4 / 1	15 / -	12 / 4	15 / -	2 / 1
	Planorbidae	*Menetus dilatatus*		2 / -			

	Viviparidae	*Campeloma decisum*	2 / -	2 / -		1 / -	
Bivalvia	Corbiculidae	*Corbicula fluminea*					7 / -
	Sphaeriidae			- / 1			

Table 3-8a. (cont'd) Macroinvertebrate species collected from tributaries in the Hardy Lake watershed

Ephemeroptera	Baetidae		- / 1				- / 1
	Baetidae	*Baetis* sp.	4 / -	2 / -			
	Baetidae	*Barbaetis* sp.			3 / -		
	Baetidae	*Procloeon* sp.	1 / -				
	Caenidae		- / 9	- / 3	- / 1		- / 1
	Ephemeridae	*Hexagenia* sp.	- / 2	- / 2			
	Heptageniidae		- / 5	- / 3	- / 29		
	Heptageniidae	*Stenacron* sp.		1 / -			
	Heptageniidae	*Stenonema femoratum*	5 / -	4 / -	23 / -		
	Leptophlebiidae	*Leptophlebia* sp.	9 / 31	9 / 29	- / 33	4 / -	- / 1

Odonata	Aeshnidae	*Boyeria* sp.	2 / -		1 / -		
	Gomphidae		- / 1				
	Gomphidae	*Gomphus* sp.	2 / -				
	Gomphidae	*Dromogomphus* sp.					1 / -
	Gomphidae	*Progomphus* sp.	2 / -				
	Calopterygidae	*Calopteryx* sp.	2 / 3	4 / -	29 / -		
	Coenagrionidae	*Argia* sp.		1 / 1			1 / 1
	Libellulidae			- / 2			

Table 3-8a. (cont'd) Macroinvertebrate species collected from tributaries in the Hardy Lake watershed

Plecoptera	Capniidae	*Allocapnia* sp.	5 / -	- / 1	3 / -	- / 19	
	Nemouridae		1 / -				
	Perlidae	*Perlinella* sp.	4 / 1		1 / -		
	Perlodidae	*Clioperla* sp.	12 / 1			13 / 2	4 / -
Hemiptera	Corixidae	*Hesperocorixa* sp.					1 / -
	Hydrometridae	*Hydrometra* sp.					2 / -

	Veliidae		1 / -				
Megaloptera	Sialidae	*Sialis* sp.	- / 2		- / 7		
Trichoptera	Limnephilidae	*Ironoquia* sp.					1 / -
	Hydropsychidae		- / 9	- / 1		- / 3	
	Hydropsychidae	*Cheumatopsyche* sp	12 / -	23 / -	1 / -	11 / -	
	Hydropsychidae	*Hydropsyche depravata* grp.		5 / -		1 / -	
	Philopotamidae	*Chimarra* sp.	- / 1			2 / -	
	Phryganeidae	*Ptilostomis* sp.	1 / -				
	Polycentropodidae	*Polycentropus* sp.					2 / -
	Rhyacophilidae	*Rhyacophila* sp.	4 / -	2 / -	1 / -		
	Uenoidae	*Neophylax* sp.	5 / -				

Table 3-8a. (cont'd) Macroinvertebrate species collected from tributaries in the Hardy Lake watershed

Coleoptera	Dytiscidae	*Brachyvatus* sp.	1 / 1		- / 1	1 / -	
	Dytiscidae	*Laccophilus* sp.					1 / -

	Elmidae		- / 1				
	Gyrinidae	*Gyrinus* sp.	2 / -				
	Haliplidae	*Peltodytes* sp.					1 / -
	Hydrophilidae	*Laccobius* sp.					2 / -
	Hydrophilidae	*Tropisternus* sp.				1 / -	
	Staphylinidae			- / 1		- / 1	
Diptera	Chironomidae		- / 3	- / 2	- / 25	- / 2	
	Chironomidae	*Chironomus* sp.		3 / -	2 / -		
	Chironomidae	*Cricotopus* sp.	24 / -	5 / -		2 / -	
	Chironomidae	*Eukiefferiella* sp.	1 / -				1 / -
	Chironomidae	*Glyptotendipes* sp.		4 / -			
	Chironomidae	*Limnophyes* sp.	1/ -	2 / -			1 / -
	Chironomidae	*Micropsectra* sp.				1 / -	
	Chironomidae	*Microtendipes* sp.	1 / -				
	Chironomidae	*Cricotopus/Orthocladius* sp.	1 / -	7 / -	3 / -		1 / -

Table 3-8a. (cont'd) Macroinvertebrate species collected from tributaries in the Hardy Lake watershed

Diptera (cont'd)	Chironomidae	*Parametriocnemus* sp.		1 / -			
	Chironomidae	*Paraphaenocladius* sp.	1 / -				
	Chironomidae	*Paratanytarsus* sp.	1 / -				
	Chironomidae	*Phaenopsectra* sp.	4 / -	8 / -			
	Chironomidae	*Polypedilum convictum*	2 / -				
	Chironomidae	*Polypedilum fallax*	1 / -				
	Chironomidae	*Polypedilum illinoense*	3 / -				
	Chironomidae	*Polypedilum scalaenum*	4 / -				
	Chironomidae	*Tanytarsus* sp.	1 / -				
	Chironomidae	*Thienemanniella* sp.	1 / -				
	Chironomidae	*Thienemannimyia* grp.	2 / -	1 / -	2 / -		
	Chironomidae	*Tribelos* sp.	2 / -	8 / -			
	Tabanidae	*Tabanus* sp.	- / 1		1 / -		
	Tipulidae		- / 1	- / 1	- / 2	- / 4	

	Tipulidae	*Antocha* sp.	4 / -			1 / -	
	Tipulidae	*Pseudolimnophila* sp.			1 / -		
	Tipulidae	*Tipula* sp.			1 / -	4 / -	

3.1.6 In-field and Analytical Chemistry Results

In-field and analytical chemistry results were collected from seven tributaries to Hardy Lake (Subwatersheds 1, 3, 4, 5, 8, 9, and 10), and from the outfall stream (Figure 2-1). The results and discussion of each sample site can be found under each subwatershed description. Figures demonstrating phosphorus levels, total suspended solids, organic nitrogen (TKN), and ammonia can be found in Figures 3-0a and 3-0b. Fluctuations in many parameters can be attributed to weather conditions and season. However, the Hardy Lake watershed appears to be a phosphorus limited system. Phosphorus limited systems typically have N:P ratios of 10:1 or greater, and ratios less than that indicate a nitrogen limitation (Horne and Goldman 1994). Higher concentrations of the common forms of nitrogen were found at all sample sites compared to phosphorus levels where all ratios were greater than 10.0.

Within each subwatershed, the average annual quantity of phosphorus entering the receiving stream (Table 3-9) was calculated by one of two methods. If P concentrations were determined through analytical chemistry results, than that value was calculated by the average annual runoff volume and converted to pounds per acre and pounds per watershed. If P concentrations were unknown, then estimates of P per land-use (Sonzogni et al. 1980) in pounds per acre were multiplied by the total number of acres of that watershed. The estimated P per land-use was then summed to obtain the concentrations of P per acre and P per subwatershed. When estimating unknown P concentrations, the P concentration per land use was given as a range of values. To ensure conservative estimates, the smallest P concentration value was used.

With one exception, it should be noted that P loading estimates could be highly underestimated due to values being based on one sampling event, by using methods that could be too conservative, and/or because this region experienced a very dry summer. The exception is in Subwatershed 5 where a field sample was collected, however, because it was below detection

Figure 3-0a. Analytical chemistry results for 5/18/99 (total phosphorus and total suspended solids)

Figure 3-0b. Analytical chemistry results for 5/18/99 (organic nitrogen (TKN) and ammonia)

Table 3-9. Phosphorus loadings per acre within the Hardy Lake watershed (P = phosphorus)

Sub-watershed	Acres	Total runoff volume (acre-ft)	P (mg/L)_	P (lbs/ acre)	P (lbs/watershed)
1	623.5	190.5	0.08	0.066	41.44
2	499.3	133.2	-	0.105*	52.43
3	682.3	197.0	0.12	0.094	64.28
4	1,699.9	621.7	0.093	0.092	157.21
5	692.2	215.3	0.049**	0.041**	28.7**
6	74.5	20.6	-	0.155*	11.55
7	108.4	25.4	-	0.132*	14.31
8	255.5	71.0	0.053	0.040	10.23
9	265.4	66.6	0.26	0.177	47.08
10	117.4	23.8	0.067	0.037	4.35
11	100.8	35.0	-	0.102*	10.28
12	120.4	43.6	-	0.152*	18.30
13	1,395.5	212.1	-	0.113*	157.69
Total	6,635.1	1,855.8	-	-	617.85

_ Measurements were directly measured from field samples

* Values are estimates based on reported values of phosphorus concentrations in agricultural land-uses.
** Field sample was below detection limit, therefore used estimate of 0.049 mg/L for calculations. The results are $\geq$ the actual value.

limit, a value of 0.049 mg/L was used to calculate pounds. The values for pounds per acre and pounds per watershed can therefore be considered equal to or greater than the actual value.

To analyze the phosphorus loading results, it was assumed that all P in the subwatershed was transported by runoff into the receiving stream. This will most likely be an overestimate in subwatersheds that have buffer zones protecting the stream or lake. However, the P loading values do identify potential areas of excessive P loading, which is particularly important since the Hardy Lake watershed is P limited.

Phosphorus loadings can be viewed graphically in Figure 3-1. A total of 617.85 pounds per Subwatershed 13 (the shoreline area) had the largest estimated phosphorus loading (157.69 lbs) which was 25.58% of the total P entering the Hardy Lake watershed. Subwatershed 4 was approximately the same contributing 25.4% (157.21 lbs). Another 11.7% came from Subwatershed 3 (64.28 lbs). All other subwatersheds contributed less than 10% per watershed.
Even though it did not contribute greatly to the overall input of P to Hardy Lake, Subwatershed 9 did have the highest P concentration per acre (0.177), followed by Subwatershed 6 (0.155) and 12 (0.152). Subwatershed 7 was also considered to have high concentrations of P per acre as well (0.132).

3.2 Subwatershed Descriptions

Problems within the Hardy Lake area were consistent among subwatersheds, and have been identified as "Areas of Concern". Areas of concern are listed at the end of each subwatershed's description, and are discussed in Section 3.2.15 . These include

A. Large average annual runoff depth

2. Low dissolved oxygen concentration

Figure 3-1. Phosphorus loadings within each subwatershed

3. High stream temperature
4. Excessive loading of organic waste materials
E. Low water flow
6. Excessive sediment loadings
G. Agriculture as the predominant land-use
H. Lack of vegetated buffer strips
1. Residential areas in the vicinity of the stream
10. Absence of wetlands
11. Problems with in-stream habitat
12. Problems in the fish community
13. Problems in the benthic macroinvertebrate community

Some subwatersheds will not include certain areas of concern because the data required to make conclusions was not collected (i.e. chemistry, habitat and/or biological data).

3.2.1 Subwatershed 1

Description

Subwatershed 1 is located in the southwest corner of the Hardy Lake watershed (Figure 2-1) and encompasses 623.4 acres (252.3 hectares). Two un-named streams drain this subwatershed; one flows west to east, and the other in a northeasterly direction. The stream flowing west to east originates within forested land. As it travels to Hardy Lake after leaving the forest, the stream flows through residential areas before entering forested land again. The forested land turns into a wetland forest, and the stream joins with the other tributary at its junction with the lake. The stream flowing in a northeasterly direction originates in agricultural fields, and travels through forested land and forested wetland before the confluence with the other tributary. Both streams are considered intermittent.

Land-Use

The dominant land-use types within this watershed are agricultural (301.3 acres, 121.9 hectares) and forest (244.8 acres, 99.1 hectares; Table 3-10). Compared to others, the average annual runoff depth per acre for this subwatershed was relatively high (3.7 inches; Table 3-3).

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Table 3-10 Land-uses within Subwatershed 1

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	244.8	99.1	39.3
Pasture/old-field	13.3	5.4	2.1
Agriculture	301.3	121.9	48.3
Residential	61.3	24.8	9.8
Water	2.7	1.1	0.5
Total	**623.4**	**252.3**	**100.0**
Wetland	52.9	21.4	8.9

Chemistry

Secchi depth readings (Table 3-11) were variable throughout the sampling period, but generally increased with decreased rainfall. Typically, turbidity is expected to increase with rain runoff. Some of the variability may best be explained by the soil permeability within the watershed. If rain events occurred when conditions were extremely dry, most rainwater would be absorbed by the soil with little runoff to neighboring streams. It was noted that 1999 experienced a particularly dry summer for the Hardy Lake area. Overall, secchi readings indicate that turbidity would be considered average for a stream with agricultural land uses.

In-field chemistry results indicate that conductivity and pH are within ranges conducive to aquatic life (Table 3-12). The dissolved oxygen concentration measured in May is at the low end of the range suitable for stream biota, and could be harmful. Stream temperature in the summer sample is also at a level considered potentially harmful to aquatic life.

Table 3-11 Stream Secchi depth readings collected from Subwatershed 1

Date	Secchi Depth (m)	24-hour Rainfall (inches)	Water Level (m)
5/18/99	0.91	0.01	--
6/11/99	0.76	0.27	0.65
6/13/99	0.53	0.79	0.66
7/7/99	1.22	0.0	--
8/3/99	0.81	0.0	0.64
8/26/99	0.81	0.57	0.66
9/21/99	0.79	0.0	0.69
10/11/99	0.58	2.0	0.69
10/28/99	No flow	0.0	No flow

Table 3-12 In-field chemistry collected from Subwatershed 1

Date	Stream Temp. (° C)	DO (mg/L)	Conductivity (umhos)	pH
5/18/99	21.4	5.30	184	7.83
7/7/99	28.9	8.14	170	8.5

Loadings of organic waste materials were considered normal in the spring samples (Table 3-13; Figures 3-0a, 3-0b) compared to average water quality ranges determined by the IDNR (Table 2-1). This stream had a N:P ratio of 15.63. Analytical chemistry was not collected in October due to no water flow.

Table 3-13 Analytical chemistry results from Subwatershed 1

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	BDL	No flow	0.05
Nitrogen, TKN	mg/L	1.25	No flow	0.10
Phosphorus	mg/L	0.08	No flow	0.05
Solids, TSS	mg/L	6.2	No flow	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.28	No flow	0.10

Areas of Concern (see section 3.2.15)

A. Large runoff volume and/or depth

B. Low dissolved oxygen concentrations

3. High temperature

D. Excessive loading of organic waste materials

E. Low water flow

G. Agriculture as the predominant land-use

8. Lack of vegetated buffer strips

I, Residential areas in proximity to the stream

Site-specific BMPs

The upper reaches of the tributary branch flowing in a northeasterly direction originate in agricultural fields with no buffer strips. By creating a vegetated riparian zone, excess sediment and/or organic waster loadings can be reduced. Other general recommendations can be found in Section 5.0, "Recommended Best Management Practices".

3.2.2 Subwatershed 2

Description

Subwatershed 2 is located at the south end of Hardy Lake (Figure 2-1), and encompasses 499.3 acres (202.1 hectares). The stream within the subwatershed flows south to north through forested land before entering Hardy Lake, and is considered intermittent. The branches to this tributary predominantly originate in agricultural land. A wetland is located at the confluence of the stream and the lake.

Land-Use

Land-use is predominated by agriculture (224.6 acres, 90.9 hectares) and forest (229.5 acres, 92.9 hectares; Table 3-14). Residential areas are limited to the outermost borders of the watershed and are not in close proximity to the streams.

Table 3-14. Land-uses with Subwatershed 2

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	229.5	92.9	46.0
Pasture/old-field	26.2	10.6	5.2
Agriculture	224.6	90.9	45.0
Residential	17.1	6.9	3.4
Water	1.9	0.8	0.4
Total	**499.3**	**202.1**	**100.0**
Wetland	11.2	4.5	2.3

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

No chemistry data were collected from this stream.

Areas of Concern (see section 3.2.15)

E. Low water flow

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

Site-specific BMPs

No site specific recommendations are made for this subwatershed. See Section 5.0, "Recommended Best Management Practices".

3.2.3 Subwatershed 3

Description

Subwatershed 3 is located in the southeast corner of the Hardy Lake watershed (Figure 2-1), and encompasses 682.2 acres (276.1 hectares). The stream within the subwatershed is considered one of the Quick Creek tributary headwaters, and flows year-round traveling approximately south to north before entering Hardy Lake. This stream flows through forested land along its entire reach. At its upper reaches, the forested riparian zone is narrower than downstream, and agricultural fields are located adjacent to the forested land. The stream flows into a wetland prior to entering Hardy Lake, and joins with the stream from Subwatershed 4. Residential areas are located close to the stream.

Land-Use

Agricultural land comprises the most area of this subwatershed (376.4 acres, 152.3 hectares; Table 3-15) with forested land also comprising a significant quantity (238.3 acres, 96.4 hectares). Compared to others, the average annual runoff depth per acre was relatively high (3.5 inches; Table 3-3).

Habitat

The in-stream habitat rating score at this site (134) is considered sub-optimal (Table 3-4) for the biological community. Possible problems are related to the amount of available instream cover (Metric 1), pool characteristics that incorporate available instream covers (Metrics 2 and 3), and sediment coming from upstream (Metric 4). See section 3.2.15, "Areas of Concern" for a full description of these problems.

Table 3-15 Land-uses within Subwatershed 3

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	238.3	96.4	34.9
Pasture/old-field	16.3	6.6	2.4
Agriculture	376.4	152.3	55.1
Residential	49.6	20.1	7.3
Water	1.6	0.7	0.3
Total	**682.2**	**276.1**	**100.0**
Wetland	32.1	13.0	4.7

Biological

The overall IBI score at this site is 40 (Table 3-5) and is considered indicative of good water quality. Nine species of fish were collected at this site. The northern creek chub was the most abundant species collected (29%). The rainbow darter was the only sensitive species collected at this site, but four species are considered tolerant. Also, two lithophilic spawners were collected at this site, the white sucker and rainbow darter. Problem areas identified in the IBI scoring are related to the presence of omnivores (metric 7; see Section 3.2.15 “Areas of Concern”).

During the March sampling event, the highest benthic macroinvertebrate taxa richness was collected at this site (Table 3-7) and this is indicative of good to excellent water quality. In total, 41 taxa were collected, and eleven were EPT species. Four of the EPT species were stonefly taxa. The community was relatively evenly distributed among the species as indicated by the low percentage of the dominant taxon (*Lirceus* sp., 25.4%) and the equitability index score (0.56). Problems within the benthic macroinvertebrate community include a low proportion of shredders (2.9%) and organic pollution, as indicated by the HBI score. The HBI score is considered indicative of fair water quality with fairly significant organic pollution. The October sampling revealed no shifts in the macroinvertebrate assemblages (Table 3-8), and the taxa collected indicated water quality was still within the good to excellent water quality. However, the FBI indicates some degree of organic pollution is occurring. See section 3.2.15, "Areas of Concern" for a full description of potential problems.

Chemistry

Secchi depth readings were variable throughout the sampling period (Table 3-16). In early summer, significant rainfall events correlated with secchi readings. However, this did not occur in late summer and fall sampling events. Typically, turbidity increases with rain runoff. This may best be explained by soil permeability within the watershed. If rain events occurred when conditions were extremely dry, most rainwater would be absorbed by the soil with little runoff to neighboring streams. It has been well documented that 1999 was a dry period for the Hardy Lake watershed. Overall, secchi readings indicate that turbidity would be considered average for a stream with agricultural land uses.

In-field chemistry results indicate that stream conditions are within ranges conducive to aquatic life, except for DO concentrations in the summer sample (3.55 mg/L, Table 3-17).

Nutrient loadings were higher in the spring than fall, and are most likely due to higher rainfall and stream flow (Table 3-18). Overall, nutrient levels were within ranges considered normal in Indiana (Figures 3-0a, 3-0b). The N:P ratio was 6.67.

Table 3-16. Stream Secchi depth readings collected from Subwatershed 3

Date	Secchi Depth (m)	24-hour Rainfall (inches)	Water Level (m)
5/18/99	0.91	0.01	--
6/11/99	0.41	0.27	0.65
6/13/99	0.33	0.79	0.66
7/7/99	0.66	0.0	--
8/3/99	0.43	0.0	0.64
8/26/99	0.61	0.57	0.66
9/21/99	0.71	0.0	0.69
10/11/99	0.76	2.0	0.69
10/28/99	0.91	0.0	--

Table 3-17. In-field chemistry collected from Subwatershed 3

Date	Stream Temp. (° C)	DO (mg/L)	Conductivity (umhos)	pH
3/23/99	5.9	13.45	434	7.80
5/18/99	17.8	7.83	540	8.18
7/7/99	22.1	3.55	577	7.52

10/28/99	8.2	6.52	450	8.94

Table 3-18. Analytical chemistry results from Subwatershed 3

Parameter	Units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.47	0.10	0.05
Nitrogen, TKN	mg/L	0.8	BDL	0.10
Phosphorus	mg/L	0.12	0.08	0.05
Solids, TSS	mg/L	4.8	BDL	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.12	BDL	0.10

Areas of Concern (see section 3.2.15)

B. Low dissolved oxygen concentration

G. Agriculture as the predominant land-use

I. Residential areas in the vicinity of the stream

K. Problems with in-stream habitat

L. Problems with the fish community

M. Problems with the benthic macroinvertebrate community

Site-specific BMPs

No site specific recommendations are made for this subwatershed. See Section 5.0, "Recommended Best Management Practices".

3.2.4 Subwatershed 4

Description

Subwatershed 4 is located at the lower east side of the Hardy Lake watershed (Figure 2-1). This is the largest subwatershed in the Hardy Lake area encompassing 1,699.9 acres (687.9 hectares). The stream flowing through the area is considered one of the Quick Creek headwater tributaries, and has multiple tributaries generally flowing east to west. At the lower reaches of the tributaries, they merge into a single stream that flows through a wetland to the lake. Just before entering Hardy Lake, this stream joins the stream from subwatershed 3. The upper reaches of each tributary flow through agricultural fields, and then through forested land along its lower reaches.

Land-Use

Agriculture is the predominant land-use within this subwatershed (1,161.0 acres, 469.8 hectares; Table 3-19), with residential areas close to the stream. This subwatershed had the highest average annual runoff depth per acre (4.4 inches; Table 3-3), as well as the highest runoff volume.

Habitat

The in-stream habitat rating score at this site (136) is considered sub-optimal (Table 3-4) for the biological communities. Possible problems are related to the degree of available instream cover and erosion (Metrics 2, 4, and 8). See section 3.2.15, "Areas of Concern" for a full description of these problems.

Table 3-19. Land-use within Subwatershed 4

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	313.3	126.8	18.4
Pasture/old-field	122.2	49.5	7.2
Agriculture	1,161.1	469.9	68.3
Residential	94.6	38.3	5.6
Water	8.7	3.5	0.5
Total	**1,699.9**	**688.0**	**100.0**
Wetland	24.5	9.9	1.5

Biological

The lowest IBI score of all sampling sites was obtained within this sample reach (38, Table 3-5). Ten species of fish were collected, and the bluntnose minnow *(Pimephales notatus*) was the most abundant fish collected comprising approximately 79% of the sample. Two species are considered sensitive, the bigeye shiner and the rainbow darter. Also, three species of lithophilic spawners were collected, the white sucker, rainbow darter, and bigeye shiner. The relatively low IBI score can be attributed to an absence of headwater species (metric 3), the presence of omnivores (metric 7), and high abundances of tolerant organisms (metric 6) and pioneering species (metric 9). This stream most likely experiences extremely low water levels periodically in the summer, and is most likely the reason for the poor metric scores. See section 3.2.15, "Areas of Concern" for a full description of these issues.

In the March sample, 24 species of benthic macroinvertebrates were collected from this stream, and nine belonged to the EPT taxa group (Table 3-7). Along with the high ratio of scrapers, these are indications of good water quality. However, there is evidence that some environmental perturbation is occurring within the watershed. These include the percentage of shredders, the high proportion of a single dominant taxon (*Lirceus* sp., 41.0%), and the HBI score (6.86) which is indicative of very significant organic pollution. The October sample indicated that some change occurred in the macroinvertebrate community (Table 3-8). Overall, only 13 species were collected, and four were EPT taxa. However, the FBI index indicated that organic pollution is not as severe as in the spring sample. See section 3.2.15, "Areas of Concern" for a full description of potential problems.

Chemistry

Secchi depth readings (Table 3-20) generally decreased after rain events, and indicate that turbidity may be greater than Subwatersheds 1 and 3.

In-field chemistry results indicate that most parameters are within ranges conducive to aquatic life (Table 3-21). The low DO concentration detected in the summer sample was most likely harmful to the stream biota.

Nutrient loadings were higher in the spring than fall, and are most likely due to relatively higher rainfall and stream flow (Table 3-22). Ammonia was present at elevated levels in the spring (Figure 3-0b). The N:P ratio was 14.4.

Table 3-20. Stream Secchi depth readings collected from Subwatershed 4

Date	Secchi Depth (m)	24-hour Rainfall (inches)	Water Level (m)
6/11/99	0.69	0.27	0.38
6/13/99	0.23	0.79	0.41
7/7/99	0.91	0.0	--
8/3/99	0.43	0.0	0.25
8/26/99	0.64	0.57	0.25
9/21/99	No flow	0.0	No flow
10/11/99	0.30	2.0	0.36
10/28/99	0.91	0.0	--

Table 3-21. In-field chemistry collected from Subwatershed 4

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
3/24/99	6.9	14.23	302	7.87
5/18/99	17.9	7.12	363	8.05
7/7/99	22.1	2.69	379	7.13
10/28/99	13.7	5.1	416	8.90

Table 3-22. Analytical chemistry results from Subwatershed 4

Parameter	Units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.51	0.40	0.05
Nitrogen, TKN	mg/L	1.34	BDL	0.10
Phosphorus	mg/L	0.093	BDL	0.05
Solids, TSS	mg/L	BDL	BDL	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.52	BDL	0.10

Areas of Concern (see section 3.2.15)

A. Large runoff volume and/or depth

B. Low dissolved oxygen concentration

D. Excessive loading of organic waste materials

E. Low water flow

F. Excessive sediment loading

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

I. Residential areas in the vicinity of the stream

K. Problems with in-stream habitat

L. Problems with the fish community

M. Problems with the benthic macroinvertebrate community

Site-specific BMPs

No site specific recommendations are made for this subwatershed. See Section 5.0, "Recommended

Best Management Practices".

3.2.5 Subwatershed 5

Description

Subwatershed 5 is located on the east side of the Hardy Lake watershed (Figure 2-1), and encompasses 692.2 acres (280.1 hectares). The stream within the subwatershed flows west to east before entering Hardy Lake, and is covered by trees for its entire length. However, it is not significantly buffered from potential sources of pollution along many reaches. In those reaches with a small buffer zone, agricultural fields are close to the stream. Prior to entering the lake, the tributary flows through a wetland area.

Land-Use

Land-use is predominately agriculture (430.3 acres, 174.1 hectares; Table 3-23) with a significant amount of forested land (211.4 acres, 85.6 hectares). Residential areas are located close to the tributary. Compared to others, the average annual runoff depth per acre for this subwatershed was relatively high (3.7 inches; Table 3-3).

Table 3-23 Land-use within Subwatershed 5

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	211.4	85.5	30.5
Pasture/old-field	24.5	9.9	3.5
Agriculture	430.3	174.2	62.3
Residential	25.3	10.2	3.6
Water	0.7	0.3	0.1

Total	**692.2**	**280.1**	**100.0**
Wetland	25.2	10.2	3.6

Habitat

The lowest habitat score was obtained at this site (91, Table 3-4). Poor available instream cover (metrics 1, 2, and 3), sedimentation problems (metrics 4 and 8), and channel characteristics (metrics 5, 6, and 7) are the primary reasons this habitat score was low. See section 3.2.15, “Areas of Concern” for a full description of these problems.

Biological

The highest IBI score was obtained within this tributary (46, Table 3-5). Four species of fish were collected where the rainbow darter was the most abundant (85.8%). Only one species, the rainbow darter, is considered sensitive to degradation, and was also the only lithophilic spawner collected. Possible problems identified within this stream reach can be attributed to the low diversity of simple lithophilic spawners (metric 11; see Section 5.2.15, “Areas of Concern”).

In the March sample, 19 species of benthic macroinvertebrates were collected within this sample reach (Table 3-7). Seven belong to the EPT taxa group, and a large proportion of scrapers were present. Despite these indications of good water quality, there is evidence that this stream is experiencing environmental perturbation. These indications include the relatively low proportion of shredders and an HBI score (6.08) which is characteristic of fairly significant organic pollution. Also, the equitability index indicates that the population is not evenly distributed among the species, as further indicated by the large abundance of one species, *Lirceus* sp. (33.0%). The October sample indicated an improvement occurred in the macroinvertebrate community (Table 3-8). The FBI index indicated that organic pollution was not as severe as in the spring sample, and the number of EPT taxa collected were relatively equal between sampling events. See section 5.2.15, “Areas of Concern” for a full description of potential problems.

Chemistry

Secchi depth readings (Table 3-24) were variable throughout the sampling period. In early summer, significant rainfall events correlated with secchi readings. However, this did not occur in late summer and fall sampling events. Typically, turbidity increases with rain runoff. This may best be explained by soil permeability within the watershed. If rain events occurred when conditions were extremely dry, most rainwater would be absorbed by the soil with little runoff to neighboring streams. It has been well documented that 1999 was an exceptionally dry period for the Hardy Lake watershed. Overall, secchi readings indicate that turbidity would be considered average for a stream with agricultural land uses.

In-field chemistry results indicate that stream conditions are within ranges conducive to aquatic life (Table 3-25).

Analytical chemistry results indicated elevated concentrations of ammonia were present in the fall sample (Table 3-26). Spring data was within normal ranges for Indiana (Figures 3-0a, 3-0b). The N:P was undeterminable due to P being below the detection limit, but is at least greater than 24.2.

Table 3-24. Stream Secchi depth readings collected from Subwatershed 5

Date	Secchi Depth (m)	24-hour Rainfall (inches)	Water Level (m)
6/11/99	0.69	0.27	0.51
6/13/99	0.08	0.79	0.53
7/7/99	0.91	0.0	--
8/3/99	0.56	0.0	0.51
8/26/99	0.33	0.57	0.51
9/21/99	0.74	0.0	0.51
10/11/99	0.89	2.0	0.53
10/28/99	0.91	0.0	--

Table 3-25. In-field chemistry collected from Subwatershed 5

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
3/24/99	11.9	14.65	370	8.64
5/18/99	18.1	10.9	435	8.53
7/7/99	21.7	7.05	504	7.93
10/28/99	6.8	7.16	414	9.03

Table 3-26. Analytical chemistry results from Subwatershed 5

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.48	0.50	0.05
Nitrogen, TKN	mg/L	1.21	0.60	0.10
Phosphorus	mg/L	BDL	BDL	0.05
Solids, TSS	mg/L	BDL	BDL	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.25	0.60	0.10

Areas of Concern (see section 3.2.15)

A. Large runoff volume and/or depth

D. Excessive loading of organic waste materials

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

I. Residential areas in the vicinity of the stream

K. Problems with in-stream habitat

L. Problems with the fish community

M. Problems with the benthic macroinvertebrate community

Site-specific BMPs

No site specific recommendations are made for this subwatershed. See Section 5.0, "Recommended Best Management Practices".

3.2.6 Subwatershed 6

Description

Subwatershed 6 is the smallest subwatershed within the Hardy Lake area (74.5 acres, 30.1 hectares), and is located in the upper east side of the watershed (Figure 2-1). The stream within the subwatershed flows approximately north to south and enters a wetland prior to entering Hardy Lake. This stream is considered intermittent. The stream is buffered on each side by a narrow row of trees, with agricultural and residential lands abutting the riparian zone. Residential areas are also in close proximity to the stream.

Land-Use

Land-use is dominated by agriculture (49.9 acres, 20.1 hectares; Table 3-27) with a significant amount of forested land (16.4 acres, 6.6 hectares).

Table 3-27 Land-use within Subwatershed 6

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	16.4	6.6	21.9
Pasture/old-field	2.7	1.1	3.7
Agriculture	49.9	20.2	67.1
Residential	5.5	2.2	7.3
Water	0.0	0.0	0.0
Total	**74.5**	**30.1**	**100.0**

Wetland	2.2	0.9	3.0

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

No chemistry data were collected from this stream.

Areas of Concern (see section 3.2.15)

E. Low water flow

G. Agriculture as the predominant land-use

I. Residential areas in the vicinity of the stream

Site-specific BMPs

No site specific recommendations are made for this subwatershed. See Section 5.0, "Recommended Best Management Practices".

3.2.7 Subwatershed 7

Description

Subwatershed 7 is located on the upper east side of the Hardy Lake watershed (Figure 2-1). The stream within the subwatershed flows from east to west and drains 108.4 acres (43.9 hectares) of the total Hardy Lake watershed area. The upper reach of the stream flows through forested land. At its lower reaches, the stream is buffered on each side by a narrow row of trees, with agricultural abutting the riparian zone. No wetlands are present along the stream reach, and the stream is considered intermittent.

Land-Use

Agriculture and forest are the dominant land-uses within this watershed (Table 3-28), encompassing 55.3 and 44.9 acres (22.4 and 18.2 hectares), respectively.

Table 3-28. Land-use within Subwatershed 7

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	44.9	18.2	41.5
Pasture/old-field	0.0	0.0	0.0
Agriculture	55.3	22.4	51.0
Residential	8.2	3.3	7.5
Water	0.0	0.0	0.0
Total	**108.4**	**43.9**	**100.0**

Wetland	0.7	0.3	0.7

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

No chemistry data were collected from this stream.

Areas of Concern (see section 3.2.15)

G. Agriculture as the predominant land-use

J. Absence of wetlands

Site-specific BMPs

Even though samples were not obtained from this subwatershed, the predominance of agricultural land indicates that this stream is most likely experiencing sedimentation, and possibly receiving excess nutrient loads and pesticides. The construction of a wetland at the stream / lake interface would reduce the concentrations of these environmental stressors before they reach Hardy Lake. Other general BMPs will also help alleviate these problems (see section 5.0, "Recommended Best Management Practices").

3.2.8 Subwatershed 8

Description

Subwatershed 8 is located in the northeastern corner of the Hardy Lake watershed (Figure 2-1), and encompasses 255.5 acres (103.4 hectares). The stream draining this watershed flows in a northwesterly direction before entering Hardy Lake and is considered intermittent. Agricultural fields, forested land, and residential areas abut the stream along the stream channel, and prior to entering the lake, the stream flows through a wetland. At its upper reaches, the stream also flows through a cow pasture.

Land-Use

Land-use is dominated by agriculture (116.1 acres, 47.0 hectares)) and forest (83.8 acres, 33.9 hectares; Table 3-29).

Table 3-29. Land-use within Subwatershed 8

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	83.8	33.9	32.8
Pasture/old-field	7.5	3.1	3.0
Agriculture	116.1	47.0	45.3
Residential	44.9	18.2	17.6
Water	3.2	1.3	1.3
Total	**255.5**	**103.5**	**100.0**

Wetland	6.5	2.6	2.5

Habitat

A habitat rating of 135 was obtained at this site (Table 3-4), and is considered indicative of sub-optimal conditions for the biological community. Problems at this site can be related to erosion (metrics 4 and 8) and the availability of available instream cover (metrics 1 and 2). See section 3.2.15, "Areas of Concern" for a full description of these problems.

Biological

This stream reach obtained an IBI score of 40 which is considered indicative of good water quality (Table 3-5). Five fish species were collected at this site, and one is considered sensitive, the rainbow darter. The rainbow darter was also the only lithophilic spawner collected. No species was numerically dominant compared to the others. The lack of simple lithophilic spawners (metric 11) indicates some level of impairment is occurring in this stream. See Section 3.2.15, "Areas of Concern".

During the March sampling event, 20 species of macroinvertebrates were collected within this subwatershed (Table 3-7), five of which were EPT taxa. However, the results of this sampling indicate some level of impairment. The community was dominated by only a few individuals as indicated by the low equitability index score, and that 90% of the population was dominated by two species, *Lirceus* sp. and the amphipod *Crangonyx* sp. Even though a significant amount of land in this subwatershed is forested, shredders were not abundant. The highest HBI score (7.72) was obtained at this site indicating possibly severe organic pollution is entering this stream. Because this stream is intermittent, no October benthic macroinvertebrate sample could be collected (Table 3-8). Problems within the macroinvertebrate community can be related to available habitat, organic pollution, and/or reduced flow. See section 3.2.15, "Areas of Concern" for a full description of these problems.

Chemistry

Secchi depth readings were only collected on two of the seven dates due to dry flow conditions (Table 3-30). Two sampling events would is not sufficient to develop conclusions.

In-field chemistry results indicate that stream temperature and dissolved oxygen are at critical levels during the summer months (Table 3-31). This is most likely a result of zero flow conditions at this time, and/or excessive nutrient loadings.

Nutrient concentrations in the spring were not indicative of problem conditions (Figures 3-0a, 3-0b). The N:P ratio was 15.5. The concentration of total suspended solids was relatively high and could be indicative of excessive sediment transport. Analytical chemistry could not be collected in October due to zero water flow (Table 3-32).

Table 3-30. Stream Secchi depth readings collected from Subwatershed 8

Date	Secchi Depth (m)	24-hour Rainfall (inches)	Water Level (m)
6/11/99	No flow	0.27	No flow
6/13/99	0.48	0.79	0.33
7/7/99	0.04	0.0	--
8/3/99	No flow	0.0	No flow
8/26/99	No flow	0.57	No flow
9/21/99	No flow	0.0	No flow

10/11/99	No flow	2.0	No flow
10/28/99	No flow	0.0	No flow

Table 3-31. In-field chemistry collected from Subwatershed 8

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
3/24/99	13.2	14.66	372	8.39
5/18/99	21.7	7.7	454	8.7
7/7/99	28.1	0.23	678	7.3
10/28/99	No flow	No flow	No flow	No flow

Table 3-32. Analytical chemistry results from Subwatershed 8

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.33	No flow	0.05
Nitrogen, TKN	mg/L	0.82	No flow	0.10
Phosphorus	mg/L	0.053	No flow	0.05
Solids, TSS	mg/L	26.2	No flow	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.13	No flow	0.10

Areas of Concern (see section 3.2.15)

B. Low dissolved oxygen concentration

C. High stream temperature

D. Excessive loading of organic waste materials

E. Low water flow

F. Excessive sediment loading

E. Agriculture as the predominant land-use

H. Lack of vegetated riparian zone

I. Residential areas in the vicinity of the stream

K. Problems with in-stream habitat

L. Problems with the fish community

M. Problems with the benthic macroinvertebrate community

Site-specific BMPs

High concentrations of organic waste material and sediment loads can partially be attributed to the presence of a cow-pasture upstream of the sample site. By ensuring that livestock are not allowed direct access to the stream and stream banks, and by creating a buffer strip or even retention pond, sediment and organic waste loads can be significantly reduced. Other general BMPs can also aid in conservation efforts in this subwatershed (see Section 5.0, "Recommended Best Management Practices").

3.2.9 Subwatershed 9

Description

Subwatershed 9 is located in the northeastern corner of the Hardy Lake watershed (Figure 2-1), and covers 265.4 acres (107.4 hectares). The stream within the subwatershed flows in a southwesterly direction and is considered intermittent. Along its reach, the stream travels through forest and cow pastures, and a wetland prior to entering Hardy Lake.

Land-Use

Forest land is the dominant land-use in this watershed (126.9 acres, 51.4 hectares), followed by agricultural fields (107.4 acres, 43.5 hectares; Table 3-33).

Table 3-33. Land-use within Subwatershed 9

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	126.9	51.4	47.7
Pasture/old-field	28.8	11.6	10.8
Agriculture	107.4	43.5	40.5
Residential	1.7	0.7	0.7
Water	0.6	0.3	0.3
Total	**265.4**	**107.5**	**100.0**
Wetland	3.7	1.5	1.4

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

In-field chemistry results indicate that during periods of flow, stream conditions are within ranges conducive to aquatic life (Table 3-34). Analytical chemistry results indicated TKN, ammonia and phosphorus levels were at extremely high levels (Table 3-35; Figures 3-0a, 3-0b). The N:P ratio was 33.0. Also, the concentration of total suspended solids was relatively high and could be indicative of excessive sediment transport.

Table 3-34. In-field chemistry collected from Subwatershed 9

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
5/18/99	22.8	7.29	547	8.4
7/7/99	No flow	No flow	No flow	No flow
10/28/99	No flow	No flow	No flow	No flow

Table 3-35. Analytical chemistry results from Subwatershed 9

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.05	No flow	0.05
Nitrogen, TKN	mg/L	8.59	No flow	0.10
Phosphorus	mg/L	0.26	No flow	0.05
Solids, TSS	mg/L	37.4	No flow	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	5.58	No flow	0.10

Areas of Concern (see section 3.2.15)

D. Excessive loading of organic waste materials

E. Low water flow

6. Excessive sediment loadings

G. Agriculture as the predominant land-use

H. Lack of vegetated buffer strips

Site-specific BMPs

High concentrations of organic waste material and sediment loads can partially be attributed to the presence of a cow pasture upstream of the sample site. By ensuring that livestock are not allowed direct access to the stream and stream banks, and by creating a buffer strip or even retention pond, sediment and organic waste loads can be partially alleviate. Other general BMPs can also aid in conservation efforts within this subwatershed (see Section 5.0, “Recommended Best Management Practices”).

3.2.10 Subwatershed 10

Description

Subwatershed 10 is located in the upper west side of the Hardy Lake watershed (Figure 2-1). The stream within drains approximately 117.3 acres (47.5 hectares) and flows in a northerly direction before entering Hardy Lake. The stream flows through agricultural land and a residential area along its upper reaches, and through pasture/old-field and forest along its lower reaches. This stream is considered intermittent.

Land-Use

Land-use is predominately forest (42.1 acres, 17.0 hectares; Table 3-36) with agriculture (29.8 acres, 12.1 hectares) and residential areas (25.4 acres, 10.3 hectares) also comprising a significant area of the subwatershed.

Table 3-36. Land-use within Subwatershed 10

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	42.1	17.0	35.8
Pasture/old-field	18.6	7.5	15.8
Agriculture	29.8	12.1	25.5
Residential	25.4	10.3	21.7
Water	1.4	0.6	1.2
Total	**117.3**	**47.5**	**100.0**

Wetland	0.2	0.1	0.4

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

In-field chemistry results indicate that during periods of flow, stream conditions are within ranges conducive to aquatic life (Table 3-37), except for DO. This level is lower than expected for spring time. Analytical chemistry results indicated TKN was slightly elevated (Table 3-38; Figure 3-0b) with a N:P ratio of 26.9.

Table 3-37. In-field chemistry collected from Subwatershed 10

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
5/18/99	16.9	5.2	222	7.68
7/7/99	No flow	No flow	No flow	No flow
10/28/99	No flow	No flow	No flow	No flow

Table 3-38. Analytical chemistry results from Subwatershed 10

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.19	No flow	0.05
Nitrogen, TKN	mg/L	1.8	No flow	0.10
Phosphorus	mg/L	0.067	No flow	0.05
Solids, TSS	mg/L	10.8	No flow	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.40	No flow	0.10

Areas of Concern (see section 3.2.15)

B. Low dissolved oxygen concentration

D. Excessive loading of organic waste materials

E. Low water flow

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

I. Residential areas in the vicinity of the stream

Site-specific BMPs

The construction of a wetland at the stream / lake interface would alleviate concentrations of potential environmental stressors before they reach Hardy Lake. Also, residential properties need to be monitored for appropriate sewage septic systems, and insure that no human activity is resulting in excessive erosion or runoff. Other general BMPs will also help alleviate these problems within this subwatershed (see Section 5.0, "Recommended Best Management Practices").

3.2.11 Subwatershed 11

Description

Subwatershed 11 is located on the west side of Hardy Lake (Figure 2-1) and encompasses 173.5 acres (70.2 hectares). The stream flows from west to east before entering Hardy Lake and is considered intermittent. The stream originates in agricultural fields and flows through forested land before entering Hardy Lake.

Land-Use

Land-use is dominated by forest and agriculture (Table 3-39) comprising 95.7 and 69.8 acres (38.7 and 28.2 hectares), respectively. Residential land is restricted to the outer reaches of the watershed.

Table 3-39. Land-use within Subwatershed 11

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	95.7	38.7	55.2
Pasture/old-field	0.0	0.0	0.0
Agriculture	69.8	28.2	40.2
Residential	8.0	3.2	4.6
Water	0.0	0.0	0.0
Total	**173.5**	**70.1**	**100.0**
Wetland	0.0	0.0	0.0

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

No chemistry data were collected from this stream.

Areas of Concern (see section 3.2.15)

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

J. Absence of wetlands

Site-specific BMPs

Even though samples were not obtained from this subwatershed, the presence of agricultural land at the upper reaches of the tributary indicate this stream is most likely experiencing sedimentation, and possibly receiving excess nutrient loads and pesticides. The construction of a wetland at the stream / lake interface would alleviate concentrations of these environmental stressors before they reach Hardy Lake. Other general BMPs will also help alleviate these problems (see section 5.0, "Recommended Best Management Practices").

3.2.12 Subwatershed 12

Description

Subwatershed 12 is located on the west side of the Hardy Lake watershed (Figure 2-1) and comprises 120.4 acres (48.7 hectares). This stream originates in agricultural land and flows in a westerly direction. Prior to entering Hardy Lake, it flows through forested land and a wetland. This stream is considered intermittent, and residential land is located in close proximity to the stream.

Land-Use

The dominant land-use in this subwatershed is agriculture (84.2 acres, 34.1 hectares; Table 3-40). Compared to others, the average annual runoff depth per acre for this subwatershed was relatively high (4.3 inches; Table 3-3), especially since it had one of the lowest average annual runoff volumes.

Table 3-40. Land-uses with Subwatershed 12

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	22.3	9.0	18.5
Pasture/old-field	5.9	2.4	4.9
Agriculture	84.2	34.1	70.1
Residential	6.2	2.5	5.1
Water	1.8	0.7	1.4
Total	**120.4**	**48.7**	**100.0**
Wetland	2.0	0.8	1.6

Habitat

An in-stream habitat evaluation was not performed at this site.

Biological

No biological samples were obtained from this stream.

Chemistry

No chemistry data were collected from this stream.

Areas of Concern (see section 3.2.15)

A. Large runoff volume and/or depth

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

I. Residential areas in the vicinity of the stream

Site-specific BMPs

Even though samples were not obtained from this subwatershed, the predominance of agricultural land indicates that this stream is most likely experiencing sedimentation, and possibly receiving excess nutrient loads and pesticides (as indicated from the P loading model). The wetland present at the stream / lake interface must be maintained and could even be increased in size. Also, the pond located along this tributary is most likely acting as a natural retention basin. By managing it as such (i.e. dredging out sediments to prevent fill-in, increasing vegetation along its banks to take up nutrients and prevent erosion, removing excess vegetation to prevent resuspension of nutrients) this pond will remain an excellent conservation tool for this subwatershed. Other general BMPs will also help alleviate these problems (see section 5.0, "Recommended Best Management Practices").

3.2.13 Subwatershed 13- Shoreline Area

Description

Subwatershed 13 is considered the land immediately adjacent to the lake, and encompasses approximately 1,395.5 acres (564.7 hectares) of the total Hardy Lake watershed area (Figure 2-1).

Land-Use

The dominant land-use in the southern portions of this subwatershed is forested land (Table 3-41). In many areas, agricultural fields abut the forest close to the lake. The northern half of Hardy Lake contains abundant residential areas adjacent to the lake. Forested land encompasses 759.6 acres (307.4 hectares) of the area, and residential land covers 187.8 acres (76.0 hectares).

Even though the shoreline area comprised the second largest area of land, it had a relatively low runoff volume and depth (Table 3-3). This is most likely due to the large amount of forested land covering this subwatershed, particularly in the riparian zone.

Habitat

An evaluation of available habitat was not performed at this site.

Biological

No biological samples were obtained from these areas.

Chemistry

No chemistry data were collected from these areas.

Table 3-41. Land-uses within Subwatershed 13

Land-use	Acres	Hectares	% of Subwatershed Area
Forest	759.6	307.4	54.4
Pasture/old-field	80.2	32.5	5.8
Agriculture	365.5	147.9	26.2
Residential	187.8	76.0	13.5
Water	2.4	1.0	0.2
Total	**1,395.5**	**564.8**	**100.0**
Wetland	12.7	5.1	0.9

It should be noted that there are significant areas of erosion on the shore banks in the northern portions of the lake (Figure 3-2; ES, personal observation). These are most likely a function of wave action caused by recreational activities.

Areas of Concern (see section 3.2.15)

D. Excessive loading of organic waste materials

F. Excessive sediment loading

G. Agriculture as the predominant land-use

H. Lack of vegetated riparian zones

I. Residential areas in the vicinity of the stream

J. Absence of wetlands

Site-specific BMPs

Even though samples were not obtained from the shoreline area, the presence of agricultural land indicates that sedimentation, and possibly excess nutrient loads and pesticides, are entering the

Figure 3-2. Lake shore erosion sites

lake in some areas. By constructing wetlands in troublesome area, these loadings could be reduced. Also, establishing “no-wake” zones to reduce boating near shorelines or constructing bank stabilization structures will help prevent erosion in problematic areas.

Residential properties need to be monitored for appropriate sewage septic systems, and to ensure that no human activity is resulting in excessive erosion or runoff, particularly for those residents with lawns that run right to the edge of the lake. Other general BMPs will also help alleviate these problems (see section 5.0, “Recommended Best Management Practices”).

3.2.14 Outlet Stream

Description

The outlet stream from Hardy Lake is located at the northern end of the lake (Figure 2-1), and incorporates the entire 7,436.6 acres (3,009.5 hectares) of the Hardy Lake watershed. The sampling reach flows through a forested riparian zone.

Habitat

The highest habitat rating was obtained in this stream reach (137), but this is considered sub-optimal (Table 3-4) for aquatic life. Possible problems at this site are related to available instream cover (metrics 1), pool characteristics (metrics 2 and 3), and sediment deposition (metric 4). See section 3.2.15. "Areas of Concern" for a full description of these problems.

Biological

This stream reach produced an IBI score of 42 which is considered indicative of good water quality (Table 3-5). Sixteen fish species were collected at this site, and three are considered sensitive, the bigeye shiner (*Notropis boops*), silver shiner (*Notropis photogenis*), and rainbow darter. The striped shiner was the most abundant species collected (51.9%). The existence of only one darter (metric 2) indicates some level of impairment is occurring in this stream. See Section 3.2.15, "Areas of Concern".

The results from the benthic macroinvertebrate community analysis also indicate some level of impairment. During the March sampling event, 19 species of macroinvertebrates were collected within this subwatershed (Table 3-7). Only three of these were EPT taxa, and none were stoneflies. Filterers were the most abundant FFG, and no shredders were present. The HBI score (5.98) indicates organic pollutants are present within the stream. See section 3.2.15, "Areas of Concern" for a full description of potential problems.

The October sampling results revealed no major shifts in the invertebrate community. The FBI score supports the March conclusion that some level of organic pollution is present in this stream (Table 3-8). However, a slight improvement over the March sample was noted with an increase in EPT taxa.

It should be noted that within this sample reach, filamentous algae have proliferated to nuisance levels (ES, personal observation)

Chemistry

In-field chemistry results indicate that during periods of flow, stream conditions are within ranges conducive to aquatic life (Table 3-42). Analytical chemistry results indicate elevated ammonia levels were present (Table 3-43; Figure 3-0b), and a N:P ratio of 18.3.

Areas of Concern (see section 3.2.15)

D. Excessive loading of organic waste materials

K. Problems with in-stream habitat

L. Problems with the fish community

M. Problems with the benthic macroinvertebrate community

Table 3-42. In-field chemistry collected from the Hardy Lake outlet stream

Date	Stream Temp. (°C)	DO (mg/L)	Conductivity (umhos)	pH
3/23/99	7.1	14.08	163	8.15
5/18/99	17.9	7.94	186	8.31
7/7/99	No flow	No flow	No flow	No flow
10/28/99	13.9	8.82	162	9.05

Table 3-43. Analytical chemistry results from the Hardy Lake outlet stream

Parameter	units	5/18/1999	10/28/1999	Detection Limit
Nitrate/ Nitrite	mg/L	0.52	0.10	0.05
Nitrogen, TKN	mg/L	1.1	BDL	0.10
Phosphorus	mg/L	0.06	BDL	0.05
Solids, TSS	mg/L	BDL	BDL	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.55	BDL	0.10

Site-specific BMPs

Because this sample site is located downstream of Hardy Lake, the problems associated with this site are predominantly a function of what is occurring within the lake, which itself is a function of what's occurring in the watershed. Nutrients that are deposited in the lake become incorporated into the sediment or biological community. Over time, through processes of uptake and decay, they will eventually travel downstream to the outlet and back into the stream. BMPs that alleviate environmental stressors within the watershed will ultimately affect the water quality and biological community at this site. Another factor that may be affecting this site involves the point of water release from the dam. If water is being released from the bottom of the reservoir, sediment and nutrients trapped in the sediment are released back into the water column for uptake downstream. See Section 5.0, "Recommended Best Management Practices".

3.2.15 Subwatershed Areas of Concern

A summary of Areas of Concern within each subwatershed can be found in Table 3-43a. The data from this study indicate Subwatersheds 4 and 9 seem to be the most impacted, and Subwatersheds 5, 10, and 12 are moderately impacted. The following is a description of each Area of Concern.

3.2.15.1 Large runoff depth

In the Hardy Lake watershed, soil characteristics are similar throughout the watershed (i.e. similar absorption capabilities) with very little impervious substrates. Therefore, even though land-use does effect runoff volume, it is considered secondary to area of land in determining the amount of runoff volume entering Hardy Lake and its tributaries. Because the area of land within each subwatershed cannot be easily altered, the average annual runoff depth per acre should be of more concern to conservation issues within this watershed. Areas with high runoff depths are more conducive to initiating erosion, and subsequently able to transport larger quantities of unwanted materials (i.e. sediment, organic waste, pesticides) to the tributary streams and/or lake. As mentioned previously, runoff depth increases with the amount of land-use in agriculture and decreases with forested land coverage. By increasing the amount of vegetated land cover within a subwatershed, particularly adjacent to tributary streams and the lake, runoff depth can be decreased.

3.2.15.2 Low dissolved oxygen concentrations

Low water temperature, increased water flow, aquatic plants and benthic algae are related to or increase DO, while high temperatures, surface algae and BOD decrease DO. Concentrations of DO below 5.0 mg/L can be harmful to stream biota. In areas of low DO, higher respiration rates

Table 3-43a. Summary of Areas of Concern within each subwatershed of the Hardy Lake region.

Sub-watersheds	1	2	3	4	5	6	7	8	9	10	11	12	13
IBI				X									
HBI/FBI				X	X		X						
Stream Habitat				X	X								
Buffer Strips	X							X	X			X	
Riparian Zones				X						X		X	X
Wetlands						X	X		X	X			
Phosphorus			X			X			X			X	
Ammonia				X	X				X	X			
TSS								X	X				
Total N (TKN)									X	X			
Temp/DO	X		X										
Watershed													

Restoration Priority	Low		Low	High	Moderate	Low	Low	Low	High	Moderate		Moderate	

are needed by fish and benthic macroinvertebrates to maintain the minimum metabolic requirements for daily maintenance and repair of the body. Therefore, less energy is available for growth and reproduction. Over time, populations of intolerant species severely decline and are eventually eliminated from the community. Undesirable organisms capable of tolerating low DO levels eventually take over and proliferate. Although low DO values can occur naturally, any management practice which effectively reduces organic wastes entering water bodies should be encouraged within the watershed. This will reduce both BOD and the potential for surface algal blooms.

3.2.15.3. High stream temperatures

High stream temperatures can be harmful to stream biota. Increases in temperature typically trigger increases in metabolism and metabolic wastes, thereby requiring higher respiration rates to obtain oxygen and remove wastes. As temperature continues to increase, this problem is compounded by the natural, inverse relationship between temperature and DO. Lower DO concentrations typically occur with higher temperatures. Water temperatures fluctuations are predominantly natural, however any human activity that removes the canopy covering the stream will increase temperatures. High temperature issues can be alleviated by maintaining forested buffer strips and active replanting of vegetation along stream banks.

3.2.15.4 Excessive loading of organic waste materials

Excessive loadings of organic waste materials can induce severe changes to physical and biological characteristics of the stream. Microbial processes that function in decay also deplete oxygen in the stream through BOD. As more waste materials enter the stream, BOD increases leaving less oxygen available to the stream biota.

In a stream environment, aquatic mosses and algae (i.e. diatoms, filamentous forms) can reach nuisance levels as a result of excess nutrients. They can particularly be harmful to fauna inhabiting the stream bottom (i.e. benthic macroinvertebrates) if they cover available habitat, or if they allow the proliferation of certain taxa that reduce the diversity and abundances of other organisms. In turn, this can effect higher levels of the food chain if specific food resources are absent or difficult to acquire. Because this watershed is phosphorus limited, any addition of phosphorus to the system will most likely result in larger abundances of aquatic mosses and algae.

Subwatersheds with large quantities of estimated P should be addressed. Subwatersheds covering larger acres of land will ultimately have large P quantities compared to smaller subwatersheds depending on land-use. This may not be of concern unless excess P is allowed to enter the stream or lake and become concentrated. Subwatersheds with higher concentrations of P per acre may be of more concern. There is a threshold of P concentration where levels above this could be harmful to aquatic ecosystems (i.e. excessive algal blooms and/or BOD). Land with high concentrations of P will most likely contribute higher concentrations per rainfall and lead to concentrations exceeding that threshold.

In a lake environment, organic waste material can induce significant algal blooms and/or excessive aquatic plant growth. When algal blooms occur, light penetration to the aquatic plants below can be reduced, thereby affecting photosynthetic rates, aquatic plant growth and the concentration of DO. If aquatic plants proliferate in the presence of excess nutrients, these dense stands of aquatic plants can prevent predatory fish (i.e. bass) from feeding on prey taking refuge within the vegetation, and can affect recreational activities such as boating.

Any management activities that reduce excessive organic waste materials should be incorporated into conservation practices. These include the presence of buffer zones between pollution sources and the water body, and monitoring residential sewage facilities and septic systems to prevent leakage or excess loadings.

3.2.15.5 Low water flow

Low flow conditions and the intermittent status of many of the Hardy Lake tributary streams can affect in-stream chemistry, habitat characteristics and the biological communities of those streams. During periods of low flow, water tends to be restricted to pool areas with little if any fresh water entering from upstream. The available habitat along stream banks and in riffle/run areas is no longer available to stream biota. Within the remaining pools, stream temperatures increase and DO concentrations decrease. The remaining biological community will consist of tolerant organisms capable of surviving these conditions. It should be noted that low water flows are a natural event that cannot be alleviated through management.

3.2.15.6 Excessive sediment loading

Excess sediment being transported downstream can affect stream biota, the quantity and quality of habitat available to stream biota, and water flow. Excess sediment can forcefully remove benthic macroinvertebrates and plants, as well as scour habitat. Interstitial spaces important to inhabitants of riffle communities become filled in, and available substrates for refugia and spawning become covered by sediment. Subsequently, these areas are no longer available to the biological community. Rapid changes to the stream channel can occur diverting water flow and possibly causing increased erosion. and unstable substrates. Management activities that retain buffer strips and prevent erosion will help alleviate excessive sediment loads.

3.2.15.7 Agriculture as the predominant land-use

Depending on the agricultural practice (i.e. row crops, livestock), excessive loadings of organic waste materials and/or sediment can occur. These problems can be compounded if livestock are allowed access to the stream. This not only allows direct deposition of organic waste, but can also reduce bank stability thereby increasing erosion and sedimentation, particularly during periods of heavy rainfall. The presence of buffer strips and agricultural practices that reduce waste loadings will help alleviate problems associated with this land-use.

3.2.15.8 Lack of vegetated buffer strips

Vegetated land and stream / lake reaches with vegetated buffer strips are capable of significantly slowing run-off and the inputs of sediment and organic waste into the water. Vegetated land acts to facilitate uptake of nutrients reducing their concentration in run-off. Within the Hardy Lake watershed, vegetated land is considered forest and pasture/old-field areas. As noted, if pasture land is used to raise livestock, then large quantities of organic waste have the potential to be flushed into the stream or lake.

3.2.15.9 Residential areas in proximity to the stream/lake

Even though residential areas do not comprise a large portion of the land use within the Hardy Lake watershed, their proximity to tributary streams and Hardy Lake demands attention. Residential homes can supply a significant quantity of nutrients if a septic system is faulty, particularly phosphorus through the use of soaps. Pesticides and fertilizers used for lawn treatment can be washed into the water and can be harmful to wildlife, both in-stream and terrestrial (for example, birds feeding on fish), and/or cause increased BOD and algal blooms.

3.2.15.10 Absence of wetlands

The important environmental stressors carried by many of the streams entering Hardy Lake are greatly reduced due to the presence of wetlands at the stream/lake interface. However, wetlands were not present at all these interfaces. Wetlands are critical ecological components vital to maintaining the health of an ecosystem because of their ability to filter contaminants before they enter the lake. Nutrients are taken up by the vegetation, and pesticides and sediment are allowed to settle out of the water column. Wetlands also function in flood control. The intermittent nature of these streams implies that during heavy rainfalls, particularly in the spring, these streams can exhibit torrential characteristics. Pollutants that settle out of the water column in pool areas will only be re-suspended and transported downstream during high water events. Wetlands function to slow water velocity and dissipate energy across a wider area, thereby preventing severe wash-out and transport of pollutants into Hardy Lake.

3.2.15.11 Problems with in-stream habitat

Stream habitat and the biological community are significantly correlated. The quantity and quality of available instream cover, pool characteristics that incorporate available instream covers and sedimentation, and riparian zone erosion were common problems with in-stream habitat of these subwatersheds. Instream cover is used by aquatic organisms for refuge, feeding sites, and spawning areas. If these areas are not available due to low flow conditions or excess sediment, the diversity and abundance of aquatic organisms in the stream will be reduced. Excess sedimentation can also reduce the diversity of available habitat that can cause shifts in community composition and abundance. The presence of buffer strips would decrease the quantity of sediment entering each subwatershed tributary, and also provide inputs of woody debris that are important as available instream cover.

Channel characteristics are also of concern because the quantity and quality of available habitat can be altered by natural or human activities that change water flow (i.e. channelization, bank stabilization, dredging). This can lead to more torrential runoff that is capable of inducing excessive erosion and scouring available habitat.

3.2.15.12 Problems in the fish community

Based on the resident fish community, the overall water quality and what is occurring within the watershed can be analyzed. Common problems within the Hardy Lake watershed were related to the presence or absence of pioneering species, omnivores, lithophilic spawners and darters.

Omnivores are indicative of environmental degradation because they are considered generalist feeders. In areas of poor water quality, the diversity of available food resources is reduced. Fish that can change their feeding habits (i.e. omnivores) can then take advantage of the available food and out-compete other species.

Lithophilic spawners require clean gravel and/or cobble for successful reproduction, and can therefore be environmentally sensitive. Lithophilic spawners disperse their eggs freely over the substrate where they develop without parental care. The low diversity of lithophilic spawners in many streams within the Hardy Lake watershed could be a result of a reduction in the quantity and quality of available substrates from excess sedimentation, or a response to dry conditions.

The presence of darters in a stream indicate the ambient water conditions are in generally good to excellent condition. Darters are generally considered sensitive to environmental stressors. They are intolerant to chemicals and organic waste, and are susceptible to sedimentation because they are lithophilic spawners. Only two darter species were found within the Hardy Lake watershed (Appendix B), one of which (the johnny darter) was not consistently found.

3.2.15.13 Problems in the benthic macroinvertebrate community

The resident benthic macroinvertebrate community is indicative of the ambient water quality conditions. They are permanent, found in all habitats and water quality, and can react rapidly to environmental change. Problems associated with the Hardy Lake subwatersheds were indicated by the HBI and FBI indices, the functional feeding groups present in the stream and taxa abundances. HBI and FBI values indicated organic pollution was entering each of the sample streams.

Scrapers, filterers and shredders were the important functional feeding groups analyzed for this study. The ratio of scrapers to filterers analyzes the ratio of species considered specialist feeders that are generally intolerant of poor water quality (i.e. scrapers) with species considered generalist feeders that can proliferate in poor water quality (i.e. filterers). FPOM is the predominant food resource of filterers, and organic wastes comprise a significant portion of FPOM. Filterers typically become abundant in areas of organic enrichment where FPOM is prevalent.

The primary food resource and habitat of shredders is CPOM. A low abundance of shredders indicates possible impacts to the quantity and quality of CPOM. Stream reaches that flow through forested land receive large inputs of CPOM, and should therefore have large abundances of shredders. CPOM can incorporate chemicals (i.e. pesticides) in tissues during the growing season, and during leaf-fall, can become available as a food resource to shredders. Because this study occurred during what was considered a dry year, and because these streams seem to be experiencing excess sediment loads, low shredder abundances may also be a function of dry conditions and/or sedimentation. Low flow conditions may have left CPOM to decay in dry stream beds.

The percent dominant taxon metric is a simple measure of the community balance among the species. In good water quality, species should be distributed relatively even throughout the community. A community dominated numerically by one or a few species is indicative of environmental stress, and tolerant organisms can become dominant at a disturbed site, particularly in areas of organic pollution (Ohio EPA 1987). Generally, the macroinvertebrate community was relatively evenly distributed among the species at each site in this project. Only within Subwatershed 8 was the community particularly comprised on one species.

3.3 Lake Monitoring

3.3.1 Lake Sites

In-field and analytical chemistry results collected from within Hardy Lake indicate conditions are within ranges conducive to aquatic life (Tables 3-44, 3-45).

3.3.2 Deep Hole

Chemistry

In-field and analytical chemistry results collected from the Hardy Lake deep hole (Figure 2-2) indicate conditions are within ranges conducive to aquatic life (Tables 3-46 - 3-50).

In-field Chemistry/Depth Profiles

The results of the in-field chemistry profiles indicate Hardy Lake is similar to other lakes of the region. This lake becomes stratified in the early summer months with warmer temperatures, thereby creating a relatively large hypolimnion (Table 3-48; Figure 3-2a). When temperatures decrease, the lake gradually mixes and decreases the cold and poorly oxygenated hypolimnetic region (Table 3-49).

Table 3-44. Secchi depth and water temperature readings collected from Hardy Lake

Site	Secchi Depth (m)	Water Temperature (° C)
1	0.94	25.3
2	0.91	25.6
3	0.94	22.9
4	0.99	24.2

5	0.91	23.7

Table 3-45. Analytical chemistry results from Hardy Lake, 5/17/99*

Site	Total Phosphorus (mg/L)	Chlorophyll a (mg/L)
1	BDL	27.0
2	BDL	21.0
3	BDL	18.0
4	BDL	27.0
5	BDL	28.0

*Phosphorus detection limit = 0.05, Chlorophyll a detection limit = 2.0

Table 3-46. Secchi depth readings collected from the Hardy Lake deep hole

Date	Secchi Depth (m)
7/7/99	2.31
10/28/99	4.57

Table 3-47. In-field chemistry collected from the Hardy Lake deep hole

	D.O. (mg/L)	pH	Conductivity (uhmos)	Temperature (° C)

10/28/99	7.72	8.95	160	14.6

*sample taken at mid-depth

Table 3-48. In-field chemistry data of the depth profile collected from the Hardy Lake deep hole, July 7, 1999

Depth (ft)	D.O. (mg/L)	pH	Conductivity (uhmos)	Temperature (° C)
1.0	7.58	8.97	184	30.4
8.0	7.33	7.76	183	29.9
13.0	6.62	7.68	180	29.3
17.0	4.59	7.20	176	26.5
21.0	0.05	7.00	200	19.5
26.0	0.04	7.14	203	18.9
31.0	0.05	7.20	216	14.0
36.0	0.1	7.42	212	11.6

Table 3-49. In-field chemistry data of the depth profile collected from the Hardy Lake deep hole, October 28, 1999

Depth (ft)	D.O. (mg/L)	pH	Conductivity (uhmos)	Temperature (° C)
1.0	8.04	8.95	161	14.0
3.0	8.16	8.96	161	14.0
6.0	8.04	8.96	159	14.0
10.0	7.00	8.90	164	14.0
13.0	6.80	8.87	149	13.6
16.0	6.71	8.86	157	13.6
19.0	6.64	8.86	164	13.5
22.0	6.14	8.83	154	13.5
26.0	5.95	8.81	168	13.4

Figure 3-2a. Depth:Temperature and Depth:Dissolved oxygen profiles of the deep hole

Table 3-50. Analytical chemistry results from the Hardy Lake deep hole

Parameter	Units	7/7/99	10/28/99	Detection Level
Nitrate/ Nitrite	mg/L	BDL	0.10	0.05
Nitrogen, TKN	mg/L	2.18	0.60	0.10
Phosphorus	mg/L	0.09	BDL	0.05
Solids, TSS	mg/L	BDL	BDL	4.0 - 5/18/99; 5.0 - 10/28/99
Ammonia	mg/L	0.61	0.60	0.10
Chlorophyll a	mg/L	380.0	N/A	2.0

3.3.3 Lake Monitoring

An index is a tool often used in data analysis which enables a researcher to collect a relatively small amount of data for the purpose of large-scale analyses. There are numerous indices available for the evaluation of lakes and reservoirs. One index used in the evaluation of Hardy Lake was Carlson's Trophic State Index (TSI; Table 3-51; Carlson, 1977). This was chosen because of its widespread use, simplicity and comparability to other lakes within the study region.

The TSI uses measurements of total phosphorus (TP), chlorophyll *a* (chl a) and transparency (SD) to describe lake trophic state by one or more numbers that emphasize the degree of enrichment in a water body. The TSI represents absolute values for chl a, TP and SD that were established by log transformations of the three variables within a scale of 1-100, so that a doubling in TP concentration is related to a reduction in water transparency by half (Cooke, et al., 1993). Depending on the values of TP, chl a and SD in the water, the index can help determine how much TP must be removed or diverted from the lake before chl a or SD values

Table 3.51. IDEM TSI Scores within Hardy Lake

July 7th 1999

Parameter	Value	Eutrophy Points	Pts. Possible
Total Phosphorus (ppm.)	0.09	3	5
Soluble Phosphorus (ppm)†	---	-	5
Organic Nitrogen (ppm)	1.57	3	4
Nitrate (ppm)	BDL	0	4
Ammonia	0.61	3	4
% DO 5ft from Surface	100%	0	4
% DO in water column >0.1%	90%	0	4
Light Penetration-Secchi Disk (ft)	7.6	0	6
Light Transmission*	48%	3	4
TOTAL		**12**	**40**

***Percent light transmission was calculated using Secchi depth**

†Sample lost or parameter not analyzed.

Table 3-51 (continued). IDEM TSI Scores within Hardy Lake

October 28th, 1999

Parameter	Value	Eutrophy Points	Pts. Possible
Total Phosphorus (ppm)	BDL	0	5
Soluble Phosphorus (ppm)†	---	-	5
Organic Nitrogen (ppm)	0.00	0	4
Nitrate (ppm)	0.10	0	4
Ammonia	0.60	3	4
% DO 5ft from Surface	75%	0	4
% DO in water column >0.1%	100%	0	4
Secchi Disk (ft)	15	0	6
Light Transmission*	69%	3	4
TOTAL		**6**	**40**

***Percent light transmission was calculated using Secchi depth**

†Sample lost or parameter not analyzed.

improve to levels detectable by lake users.

For example, the range between TSI values of 70 and 80 represents a highly eutrophic lake. Between these two points, TP doubles (from 48 to 96 mg/L) and SD is halved (from 0.5 to 0.25 meters). If a management plan was implemented which cut the TP concentration in half and decreased the TSI value of a lake from 80 to 70, this would indicate a successful phosphorus treatment to lake managers, but not to lake users, who would not be able to detect the small improvement in SD of 0.25 meters. However, if a lake has an original TSI value of 50, a reduction in TP by half (12 mg/L) would be a smaller TP decrease than the above example and may not suggest a successful TP diversion to lake managers, but would present to lake users an impressive increase in transparency (SD) of two meters (Carlson, 1977). This suggests that highly enriched lakes, with high TSI values will need more aggressive phosphorus reduction plans in order for changes in lake conditions to be detectable. If a lake is highly eutrophic, relatively small decreases in lake phosphorus concentrations will not likely result in any real changes in lake chemistry, the amount of algae or aquatic plants present or the fish community composition.

The TSI values for Stations L1-L5 (Figure 2-2) were approximately 60 for all three variables (SD, TP, chl a). TP at Stations L1-L3 were below the detection levels of 50 mg/L, but were assumed to be similar to the TP levels at Stations L4-L5 (approximately 57 mg/L). This indicates slightly eutrophic conditions in Hardy Lake. A reduction of TP by half (24 mg/L) would likely result in an increase in SD of one meter and a decrease in chl a of over 13 mg/L; changes that would be detected by lake users and which would positively affect lake conditions.

Sometimes the TSI value determined by TP does not coincide with the value determined by SD. When this occurs, it indicates that some other factor may be influencing one of the index variables and that a direct relationship may not exist between TP, chl a and SD. This seems to be the case at the deep water sampling location (DH-1). Measurements for the three variables coincide with TSI values of 50 (SD), 70 (TP), and 90 (chl a). The SD value, as determined from field measurements, was higher at

DH-1 than at the shallow areas of the lake because this site was in deep, open water. By the time inflowing water had reached this sampling location, the suspended solids entering the lake had been filtered out by aquatic plants present near the shoreline or had simply settled out of the water column. This led to a higher transparency and SD value at the deep sampling site, which would give a lower (SD) TSI value than at the shallow sites. Also, resuspension of bottom sediments is unlikely to occur at the deep site, but probably occurs frequently at the shallower sampling sites, where it may reduce transparency and result in a higher (SD) TSI value than at station DH-1.

The difference in TP and chl *a* between the shallow sites and site DH-1 is believed to be a function of water sample collection methods and chl a analysis by Environmental Control Laboratories. At Station DH-1, a composite water sample made up of water collected at the surface, 5.0 meters and 11.0 meters was analyzed for TP and chl a. Water samples at all other sampling stations were collected only near the surface. Cold, dark water near the bottom of the lake is separated and prevented from mixing with warm, well lit water near the surface of the lake. In these bottom waters, DO levels can decrease to 0.0 mg/L and TP levels can rapidly increase due to the release of phosphorus from the lake sediments. This phosphorus remains isolated from the upper water layers until the lake turns over in the autumn. However, when water collected from all three depths at the deep water site was combined into a composite water sample for testing, this highly enriched bottom water was mixed with surface water which is relatively low in TP. This resulted in a deep water sample with a TP level nearly double the levels measured at all other shallow sampling sites (where water was only collected at the surface), and a (TP) TSI value for the deep hole site that did not coincide with the corresponding TSI value based on SD measurements.

This combination of water samples from different depths, along with a delay in sample analysis, may also have affected chl a levels. When phosphorus-rich water from the lake bottom was combined with phosphorus-limited surface water, the algae present in the surface water began using phosphorus and light to grow. Chlorophyll, as an indicator of algae concentration, would have increased in the samples in response to the growth of algae. For this reason, the water samples collected for the analysis of chl *a* are, typically, not exposed to light and are analyzed very shortly after collection in the field so that true chl a levels can be determined. Due to improper handling in the laboratory, the water sample collected from the deep water station in Hardy Lake was not analyzed in a timely manner and was exposed to small amounts of light before analysis. This gave the algae the time and resources (light and phosphorus) necessary to increase its density to levels higher than what was originally in the surface water of Hardy Lake, and resulted in a (chl a) TSI value much higher than was indicated by TSI values determined from TP and SD.

3.3.4 Aquatic Plant Survey

On July 8th and 9th, 1999, EnviroScience completed a qualitative aquatic plant survey throughout Hardy Lake (Figure 2-2). In total, twenty three species were encountered (Table 3-52).

Seven sampling sites (M-1 through M-7) were established for rake tow samples on the perimeter of Hardy Lake (Figure 2-2). Sample site M-1 included six different species with the most dominant being Eurasian watermilfoil (*Myriophyllum spicatum*) with 40% abundance (Figure 3-3). Slender pondweed (*Potamogeton pusillus*) is considered a "state rare species" and contributed 20% of the population at Site M-1 (Figure 3-4). Site M-2 had the most diverse aquatic plant population of all sampling sites with eight species. The dominant species was both
Eurasian watermilfoil and northern water nymph (*Najas flexilis*) with 30% abundance each (Figure 3-5). Sample M-3 included six species and had a mono-culture of coontail

Table 3-52. Aquatic Plant Species List

Common Name	Scientific Name	Control Method
algae	*Rhizoclonium*	Copper Sulfate / Cutrine
algae	*Cladophora*	Copper Sulfate / Cutrine

algae	*Nitella hyalina*	Copper Sulfate / Cutrine / Aquathol
American Lotus	*Nelumbo lutea*	Sonar
Broad Leaved Arrowhead	*Sagittaria latifolia*	Sonar
Common Cattail	*Typha latifolia*	Rodeo / Reward
Northern Watermilfoil	*Myriophyllum sibiricum*	Sonar
Coontail	*Ceratophyllum demersum*	Sonar / Cutrine / Reward
Creeping Primrose Willow	*Jussiaea rapens*	Reward / Rodeo
Curly Leaf Pondweed	*Potamogeton crispus*	Sonar / Aquathol / Reward
Brushy Pondweed	*Najas minor*	Reward / Sonar
Eurasian Watermilfoil	*Myriophyllum spicatum*	Sonar / Reward
Greater Duckweed	*Spirodela polyrhiza*	Cutrine / Reward
Longleaf Pondweed	*Potamogeton nodosus*	Sonar / Aquathol / Reward
Marsh-Willow Herb	*Epilobium palustre*	
Muskgrass	*Chara* sp.	Copper Sulphate / Cutrine / Aquathol
Slender Naiad	*Najas flexilis*	
Purple Loosestrife	*Lythrum salicaria*	2-4D / Rodeo
Road Grass	*Eleocharis baldwinii*	
* Slender Pondweed	*Potamogeton pusillus*	Do Not Spray
Soft Rush	*Jancus effusus*	Sonar
Soft-stem Bulrush	*Scirpus validus*	Navigate / Reward / Rodeo
Square Stem Spike Rush	*Eleocharis quadrangulata*	Sonar / Reward / Rodeo

*Considered State Rare Plant

Figure 3-3. Site M-1 aquatic plant dominance in Hardy Lake

Figure 3-4. State rare plant slender pondweed (*Potamogeton pussilus*) distribution within Hardy Lake

Figure 3-5. Site M-2 aquatic plant dominance in Hardy Lake

(*Ceratophyllum demersum*) which was 80% dominant (Figure 3-6). Sample site M-4 also included six species, but showed a more diverse abundance with northern water nymph, eutrophic water nymph (*Najas minor*) and Eurasian watermilfoil having a percent composition totaling 75% (Figure 3-7). Although small amounts of Eurasian watermilfoil were observed in the area, Sample M-5 was 100% composed of coontail (Figure 3-8). Sample Site M-6 was dominated by three species with included coontail, eutrophic water nymph and northern water nymph which contributed 50%, 25% and 25%, respectively (Figure 3-9). Sample M-7 was
comprised of seven species with the most dominant being eutrophic water nymph at 40%. Coontail and Eurasian watermilfoil comprised 2% and 10%, respectively (Figure 3-10).

Distribution maps of dominant or significant plant species of Hardy Lake were generated using GPS and GIS mapping technology. Figures 3-11 through 3-15 show the distribution of sparse and major populations of coontail, Eurasian watermilfoil, American lotus (*Nelumbo lutea*), common cattail (*Typha latifolia*), and purple loosestrife (*Lythrum salicaria*) throughout the lake. The numbers within the map key relate to a qualitative assessment of abundance based on field observations. A rating of “1" indicates a sparse population while a “5" relates to an abundance greater than 80%. A rating of “3" indicates 40-50% abundance within the area.

Figure 3-11 presents the distribution of the exotic Eurasian watermilfoil. This invasive milfoil does not contribute more than 80% of the population at any one observed area and almost always coexisted with other plant species.

Figure 3-12 shows the distribution of coontail in Hardy Lake which indicates that in the southern portion of the lake it is especially abundant. At several locations coontail comprises 90 to 100% of the plant community. Overall, field observations indicated that coontail was the most dominant aquatic plant species in Hardy Lake.

Figure 3-6. Site M-3 aquatic plant dominance in Hardy Lake

Figure 3-7. Site M-4 aquatic plant dominance in Hardy Lake

Figure 3-8. Site M-5 aquatic plant dominance in Hardy Lake

Figure 3-9. Site M-6 aquatic plant dominance in Hardy Lake

Figure 3-10. Site M-7 aquatic plant dominance in Hardy Lake

Figure 3-11. Eurasian watermilfoil distribution within Hardy Lake

Figure 3-12. Coontail distribution within Hardy Lake

Figure 3-13. Purple loosestrife distribution within Hardy Lake

Figure 3-14. Cattail distribution within Hardy Lake

Figure 3-15. American lotus distribution within Hardy Lake

Figure 3-13 shows the abundance of the exotic purple loosestrife. The largest populations of purple loosestrife were observed in the mid portion of Hardy Lake on the western shoreline.

Figure 3-14 presents the distribution of common cattail. Even though the distribution of cattail is widespread, dense populations are limited to backwater areas and stream inputs.

Figure 3-15 shows the presence of American lotus. Where found, the American lotus often comprised between 80% and 100% of the aquatic plant population. The largest population exists in the southern portion of the lake extending out as far as 300 yards from shore.

Table 3-52 presents possible herbicide controls for the problem aquatic plants encountered in Hardy Lake. At present, EnviroScience identified five species of aquatic plants which should be considered for control. These include American lotus, coontail, Eurasian watermilfoil, muskgrass and purple loosestrife. Although EnviroScience does not recommend a lake-wide spraying program, application of herbicides will likely provide the most cost effective method of control for these invasive species.

Hardy Lake has many uses which could make a chemical application problematic. The use as a public water drinking supply may limit the number and types of chemicals that can be applied to certain areas and possibly the lake as a whole. The aquatic plant beds which contain slender pondweed (*Potamogeton pusillus*) should be avoided due to its listing as a "state rare species". Another consideration is the Hardy Lake fishery. In certain areas, spraying herbicides to control coontail (*Ceratophyllum demersum*) can increase habitat availability. Limited control could result in additional ambush points for sport fish for feeding, spawning and nursery areas, and habitat for life histories of resident fish communities. If considered at all, these control methods should be done in moderation. The complete eradication of aquatic plant beds can result in habitat loss and impact the fishery as a whole. If a chemical application program is considered for Hardy Lake, the involvement of IDNR fishery managers, health officials and lake managers would be crucial. Also, the total effect of grass carp previously stocked for weed control have not yet been realized. Additional stockings would not be recommended due to the damage that can occur from overstocking and the non-selective control which these fish provide. A total of 1,150 grass carp were originally stocked in Hardy Lake in June 1996. Because the life span of these fish can live upwards of eight years, it is highly probable most still exist. Many were observed during the macrophyte survey. It is recommended that Hardy Lake managers continue to monitor aquatic plants to guard against the establishment of other invasive species. Chemical applications are much more effective and economical at the onset of a problematic aquatic plant population.

3.4 Secondary Source Review

The secondary source review was completed by EnviroScience with the assistance of the Jefferson and Scott Counties SWCD personnel. All pertinent information collected as part of this task was used in the development of the GIS or evaluations completed as part of the project. Information reviewed can be found in Appendix H.

4.0 Conclusions

4.1 Subwatershed summary

As in many rural watersheds, environmental stressors to the Hardy Lake watershed are predominantly associated with agricultural practices.   All subwatersheds studied exhibited some degree of impairment due to sedimentation from land use practices, and some select watersheds were somewhat impaired by loading of organic wastes. However, based on the data collected in 1999, the Hardy Lake watershed should be considered in "good" condition relative to other lakes in Indiana, with a few problem areas. The macrophytes present in the lake were generally not problematic, and both the fish and macroinvertebrate community were comprised of intolerant species. Chemical parameters in the lake and watershed streams were normal for this region of Indiana accounting for seasonal variation. Considering that Hardy Lake proper was found to be mildly eutrophic, there exists strong potential for watershed restoration projects to have measurable effects on improving the lake's overall water quality. This means that improvements in the water quality of a few selected inputs could result in noticeable benefits to Hardy Lake.

If improperly managed, agriculture can result in stream and lake impairment for many reasons. The primary sources of agricultural non-point source pollution are sediment, nutrients, animal wastes, and pesticides. Other impacts of agriculture include in-stream habitat destruction by livestock and equipment. This is particulary true in areas which have highly erodible soils. Excess sediment from erosion can reduce the quantity and quality of substrates by disrupting the riffle-pool complexes. These sediments are unstable within the stream and tend to re-suspend during high flow events. Ultimately, biologically sensitive available instream covers (stream substrates available to aquatic life) are covered, particularly during periods of low flow, and scoured during high flow events. Sediments are eventually transported downstream and deposited in wetlands at the interface with Hardy Lake and/or directly into the lake itself. Such sedimentation will eventually cause premature filling of the lake.

Nutrient loadings can occur from animal waste, faulty septic systems, and fertilizer applications. Nutrient inputs can enter streams directly, or indirectly via attachment to sediment particles. As with sediments, excess nutrients can eventually enter Hardy Lake. Phosphorus and nitrogen are the two primary nutrients associated with agricultural non-point pollution. If excessive nutrient loadings occur in the lake, these nutrients will cause problematic algal blooms and/or aquatic plant growth. Excess plant growth can reduce the amount of light reaching bottom vegetation that serves as an important food source for some wildlife, and habitat and refugia for many other biota. The resulting biological oxygen demand from decomposition of the plants and algae at the end of the growing season will result in a decrease in the levels of oxygen available to aquatic life, and can result in an increase in less desirable fish species which are tolerant to low dissolved oxygen levels. As excess plant growth decomposes year after year, the resulting detritus can shorten the life span of the lake as well.

4.3 Lake Summary

Hardy Lake exhibited characteristics of a mildly to moderately eutrophic lake in 1999 based on the Trophic State Index values. This data suggests that phosphorus may be limited by the aquatic plant community, at least during dry periods. Most of its tributaries also showed the effects of moderate nutrient loads. However, 1999 was one of the hottest, driest years on recent record. During the summer months there were few rain events significant enough to cause the torrential stream flows in the tributaries normal to the region. In effect, the normal hydrological processes were interrupted. This condition made characterization of the lake difficult. However, the biological fish and macroinvertebrate data collected seemed to work well at categorizing the tributaries and identifying problem areas.

The aquatic plant survey completed in July showed that a diverse plant community exists in Hardy Lake, with some possible nuisance plant growth occurring in certain areas later in the year. Controlling plant growth in these nuisance areas could improve fishery production and boat access. However, because phosphorus may be limited by aquatic plants, control should be moderate and over a period of time to prevent accelerated eutrophication. Also, the long term effects of stocked white amurs (grass carp) on the aquatic plant community have probably not yet reached an equilibrium. EnviroScience recommends that a modest weed control program be initiated in the southern end of the lake. There are many types of weed control products available for safe use in drinking water supply reservoirs. EnviroScience can develop a specific weed control program at the request of the lake managers.

The IDNR completed a fisheries survey of Hardy Lake in 1999. While the results of this report are not yet available, Larry Lehman (IDNR, Fisheries Section) and EnviroScience discussed some possible management options for the fishery. These included:

- selective, moderate control of aquatic plants in the shallow, southern end of the lake to reduce the amount of cover for bluegill species from largemouth bass.

- cutting submerged logs and marking a navigable boat access channel into the southern end of the lake to provide fishing access. (This could possibly be done during a period of low water levels with a chain saw from a boat or when the lake is low and safely frozen during the winter)

- Conduct a creel survey at launch ramps to assess fishing pressure and fish harvest

The watersheds were evaluated on an individual basis and that information will not be repeated here. Please see Section 3.0, Results for discussions on the specific sub-watersheds.

4.2 Overall Study Findings

This study suggests that phosphorus is a limiting factor in Hardy Lake. There are a few subwatersheds that EnviroScience believes are contributing the majority of the phosphorus input to Hardy Lake. These subwatersheds are #3, #4, #9 and #12. There are also specific subwatersheds which provide a large percentage of the inflowing water each year and future rehabilitation and protection efforts should focus on protecting them from further development. These subwatersheds are #3, #4, #5, and #12. Based on the surrounding land use, Subwatersheds 1, 3, 4, are 12 are comprised of a large proportion of agricultural land, some of which is in close proximity to the stream. Therefore, there should be a concentrated effort on preserving adequate riparian zones in these areas.

Due to extremely dry conditions in 1999, the results of this study must be considered preliminary. Little rainfall during 1999 meant that no high-flow data were collected from the tributary streams, and that samples from all the chemistry sites were collected only one time. Based on the torrential nature of Hardy Lake's tributaries, it is likely that most of the nutrient and sediment input into the lake occurs during two or three extremely high flow events each year. Such events should be sampled in order to develop more robust sediment and nutrient models. This study did not obtain data on such events, but it does provide a guide to as which subwatershed areas are most important to lake health, and which areas would provide the most benefit from restoration.

5.0 Recommended Best Management Practices

The purpose of the Hardy Lake Watershed Study was to serve as a baseline study providing valuable information on possible environmental stressors to the lake and its watershed. This study is the first step in a holistic management approach to improve water quality and extend the recreational and overall life of the reservoir. The resulting data from the study identified some potential problems with the watershed that should be addressed to protect this valuable natural resource. EnviroScience has listed some Best Management Practices (BMPs) which should be considered for Hardy Lake and the Scott and Jefferson Soil and Water Conservation Districts.

5.1 Public Awareness and Continued Monitoring

The Scott and Jefferson County Soil and Water Conservation Districts have limited watershed management resources. However, public awareness and involvement can eventually lead to public responsibility. The people that use and live on Hardy Lake represent an untapped resource for lake restoration. The following BMPs were designed to get the public involved and to build on the baseline study completed in 1999.

Public Awareness- The Scott and Jefferson County Soil and Conservation Districts should consider a joint informal meeting with the community members living in the watershed of Hardy Lake. Structured much like the Scott County SWCD Day, this event could bring parties from both counties together to coordinate some simple lake restoration projects. Details of the meeting could include an explanation of the responsibility of the SWCD's, the results of the study, and a "where should we go from here" discussion. The purpose of the meeting would be to spark interest within the community and lay the ground work for a volunteer monitoring program.

Volunteer Monitoring Program- The study completed in 1999 is a baseline study and would benefit from additional data collection during a year of normal rainfall. This data can then be used to monitor changes within the watershed and measure the success of management practices. An example of a simple program would be for volunteers to continue to collect stream data (total phosphorus, ammonia, stream Secchi depth, suspended solids, and water level) from the 8 stream chemistry sites after significant rain events. Also, data could be collected from the lake monitoring sites (Secchi depth, chlorophyll a, and total phosphorus) once a month as well. The data could be submitted to the Indiana Department of Natural Resources for comparison to other lakes in the area. A volunteer lake monitoring program allows individuals to be involved and take responsibility for the future of Hardy Lake. The cost of the simple chemistry analysis could be shared between the SWCDs or funded by the state. The state of Indiana currently has two volunteer programs in existence, the Hoosier Riverwatch volunteer stream monitoring program at IDNR (317-233-3870) and the Lake Volunteer Monitoring program at IDEM (317-308-3217).

5.2 Nutrient and Sediment Control

Nutrient and sediment loading have been identified as two of the environmental stressors within the Hardy Lake watershed. This is a sensitive issue considering that most of the surrounding land use is agricultural. Through a combination of public awareness and communication, BMPs which address some of these issues can be approached by the Soil and Water Conservation Districts.

Conservation Buffer Strips- Buffer strips are vegetated areas adjacent to stream banks. They function as filters for surface water runoff which contains sediments and nutrients. Some of the tributaries which feed Hardy Lake did not have sufficient buffer zones. This is particularly harmful in pasture areas where livestock can walk through the stream, re-suspending sediments and adding animal waste products. Evidence of such activities can be seen in subwatersheds #9, #4, and #8. The sponsoring SWCDs may want to investigate these areas and help farmers implement adequate buffer strips.

Establishment of Warm-Season Grasses- Warm-season grasses such as native, perennial, sod-forming tall grasses provide excellent erosion control and wildlife cover for conservation. Warm-season grasses can be established in washout areas and waterways of agricultural fields to prevent sediment transport. Examples of waterway construction and warm-season grass establishment were presented by Ed Roll of the IDNR at the Scott County SWCD Field Day on September 11th, 1999.

Stormwater conveyance channel- A stormwater conveyance channel is a permanent waterway or ditch lined with vegetation, matting or riprap and used to transport stormwater runoff without channel erosion. These channels should be placed in areas where improved drainage or stormwater transport is needed, or plants and riprap should be placed in existing channels to slow water flow and reduce sediment and nutrient transport.

Eddy Rocks- Eddy rocks are large rocks grouped in a stream channel in order to dissipate high- flow energy, improve channel appearance and provide habitat, such as calm eddies, protective cover, and deep scour holes within the stream channel. These rocks may be used where erosive water flow needs to be reduced or where stream habitat needs to be improved.

Silt fencing- Silt fencing is most commonly used to limit the amounts of sediments entering a stream during a construction project. With proper maintenance, it can capture a large percentage of the sediments which otherwise would end up in the receiving streams. This may also be an option for areas which have row crop land use without an adequate buffer zone. This would reduce the number of top soil washouts entering the receiving stream and benefit the farmer with retention of valuable top soil. However, silt fencing should only be considered a short term BMP, and buffer strips would be more appropriate for the long term.

Fences to prevent grazing- Although not typically well received by farmers with livestock, fencing off stream sections from grazing livestock is an excellent method for controlling bank erosion and nutrient loading. Keeping the animals out of the stream reduces sediment re-suspension and the addition of animal waste products. Provisions must be made which allow the land owner access to the stream in certain areas to provide water for livestock. Many states have received grants or practice cost-sharing to purchase and install fencing in order to make the idea more appealing to the land owner.

Additional water sources for livestock- Some studies have shown that additional drinking water locations reduce the amount of time livestock spend in a stream. This can result in less animal waste in the stream and less damage to the surrounding stream bank.

Manure Composting Structures- Manure composting structures create a holding facility for animal waste products before land application. They are typically used in dairy farming where animals are contained in a relatively small area. The manure is treated and turned into valuable compost which can be applied as fertilizer to farm fields. These structures are beneficial to the environment and land owner. They prevent additional nutrient loading to neighboring streams during rain events while providing a valuable resource to farmers in the form of fertilizer.

Precision Farming- The primary source of most nutrients and pesticides entering watersheds from agricultural land use is fertilizer. A reduction in the amount of fertilizer spread on a field results in a decrease in the amount entering surface waters. Precision farming is a technology that should be explored by the both Conservation Districts. An informative example of precision farming was presented by Doug Burns on September 11th, 1999 during the Scott County SWCD field day. The technology helps farmers identify soils which are nutrient rich and do not need additional fertilizer, as opposed to those soils which need nutrient enrichment. Precision farming uses Global Positioning

Technology to map farmers' fields and facilitate the development of application rates. Although start up costs may be considerable, a reduction in fertilizer application reduces the overall costs for the land owner. In many instances, the realized savings on applications can pay for the system in the first two or three years. Grants for such programs may be available through state or federal agencies.

Sediment traps- Possible future land development in the Hardy Lake watershed could add large amounts of sediment, and possibly toxins, to the inflowing streams. Sediment traps are temporary settling ponds which have a single spillway outlet stabilized with geotextile and riprap. These ponds can detain large amounts of dirt and mud in runoff before it enters the lake. From the data gathered in this study, it appears Subwatersheds 8, 9, 10, and 12 would benefit most from sediment traps. This conclusion is based on nutrient and sediment loads, and the surrounding land use, particularly the presence of agricultural fields and wetlands.

Mulching- The application of a protective layer of mulch to bare soil is used to abate erosion by shielding it from raindrop impact, helping establish vegetation by conserving moisture and creating favorable conditions for seeds to germinate. Mulch should be used on a construction site throughout construction to limit the areas that are bare and more susceptible to erosion. Mulch can be used in conjunction with seedling to establish vegetation or by itself to provide erosion control during the winter, when vegetation will not grow. Mulch and other vegetative practices should be applied on all disturbed portions of construction sites that will not be re-disturbed for more than 45 days.

Temporary seeding- Temporary seeding provides erosion control to areas in between construction operations. Quick growing grasses are seeded and usually mulched to provide prompt, temporary soil stabilization which effectively minimizes the area of a construction site prone to erosion. Plants should be used everywhere the sequence of construction operations allow vegetation to be established.

Permanent seeding- Permanent seeding involves the establishment of perennial vegetation used to permanently stabilize soil, prevent sediment pollution, reduce runoff by promoting infiltration and provide stormwater quality benefits offered by heavy vegetation. Permanent seeding should be used in areas of construction sites which can be brought to final grade or in areas that will be re-graded, but will lie dormant for a year or more.

Sodding- Sod is used to provide immediate soil stabilization in erosive areas, such as construction sites or steep slopes, and may be used where immediate cover is required and where vegetation will provide adequate stabilization.

Matting- Matting such as excelsior or jute matting is used to stabilize easily eroded areas while vegetation is becoming established and should be used on channels with high flow, steep slopes, construction areas with highly erosive soils and areas that may be slow to establish adequate vegetative cover.

Tree Preservation Area- Trees that exist on construction sites prior to development may be protected so they will continue to survive after construction. Tree preservation areas may be used to protect areas of forest along streams which serve as buffer strips and reduce the amount of sediment and nutrients entering the stream. Planning considerations to employ before construction begins include forest delineation, altered site plans, protection during construction and permanent visual barriers.

Non-sediment Pollution- Although sediment is typically the primary pollutant resulting from construction activity, other pollutants such as petrochemicals, construction chemicals, solid wastes and construction debris need to be considered as well. Good erosion and sediment control will prevent some pollutants and sediments from leaving the construction site. However, pollutants carried in solution or as surface films in runoff water will be carried through most erosion and sediment control practices. So, while typical erosion and sediment control practices are important for controlling other pollutants, additional preventative measures are needed for non-sediment pollutants. Reducing pollutants heavily depends on construction personnel and how they carry out their operations. In order to help facilitate good practices on-site, plans should contain standard notes clearly stating requirements for contractors.

Stream Bed and Bank/ Lakeshore Restoration- There are many methods of streambank erosion control which are relatively simple to implement. Methods such as brush mattressing, brush layering, branch packing, and joint planting are all restoration methods which use live cuttings to provide stability to sensitive erosional areas. Streambank stabilization uses plant materials to control streambank erosion, provide interim bank protection and introduce tree species with a thick network of roots along streambanks. This practice not only introduces new habitat along the stream, but reduces sediment loading to the stream via erosion during high water flow. This report identified problem areas of shore erosion along Hardy Lake. In addition, SWCD personnel could help identify and rank erosional problem areas within the target restoration subwatersheds outlined in this report. Such restoration methods could possibly be funded by the Lake and River Enhancement Program. Illustrated examples of shore stabilization methods can be found in *Landscaping for Wildlife and Water Quality*, available for purchase from the Minnesota Department of Natural Resources, or through EnviroScience, Inc. This inexpensive book provides excellent illustrations and guidance for landowner conservation measures.

Residential Areas- Residential areas can be major sources of phosphorus through the use of lawn fertilizers and laundry detergent. By limiting allowable fertilizers to those containing little or no phosphorus, and by inspecting and maintaining septic systems, P loading can be reduced.

5.3 Hardy Lake Recreation

One of the most noticeable functions of Hardy Lake is its function as a recreational opportunity to local residence and visitors. Although this study did not concentrate on the recreational value of the lake, certain BMPs can be recommended based on observations and communications with the sponsoring agencies.

Aquatic Plant Control Program- An aquatic plant control program is often used by lake managers to improve the recreational opportunities available to lake users. The control of aquatic vegetation and exotic species around boat ramps and swimming areas often results in a positive reaction to people visiting the lake. After all, this is the first place a person sees when visiting the lake. If the lake is to be used as a fishing resource, aquatic vegetation is very important. Certain species of plants provide cover necessary for the life histories of resident fish communities while providing fishable structure for fisherman. As mentioned previously in this report, because phosphorus is likely limited in Hardy Lake by aquatic plant growth, overzealous control measures could accelerate the eutrophication process. Any control program should start with identifying the areas and uses to be managed. With the help of a qualified applicator, the information contained in this report, fisheries biologists, and SWCD personnel, a successful aquatic plant control plan for Hardy Lake can be developed.

Improve Available Habitat for Fish- Often times, habitat is the limiting factor for fish populations in large reservoirs. Habitat provides opportunities for predation, spawning, nursery areas, and cover. While there is more than adequate habitat for fish in the southern end of the lake, the northwestern half of the lake could benefit from the installation of artificial underwater habitats. Habitats available commercially (such as the Fish Crib™) are invisible to fish-finding sonar, yet provide cover and ambush points for larger fish such as hybrid muskellunge or largemouth bass. These commercial habitats can be set up quickly so that fishermen are unaware of their location to prevent excessive fishing pressure. Fisheries managers from the IDNR could help identify areas which should be targeted for habitat placement and the target species. These habitats could also be constructed with relatively inexpensive materials often being donated by residents or local businesses. Habitat to be considered can include, but not be limited to stacked tires, concrete blocks, clay pipe, or pea gravel.

5.4 General Best Management Practices

General BMPs are those which do not fit into specific headings or have the direct involvement of land owners. These BMPs are best initiated and completed by the local SWCDs.

Purchase Environmentally Sensitive Properties- One of the options to be considered by the Scott and Jefferson SWCD is to secure funding through grants to purchase conservation easements to protect environmentally sensitive areas within the Hardy Lake Watershed. Land purchases would need to be prioritized by the benefits of green space within the subwatersheds that have been identified as having environmental stressors. Naturally, preventing development in areas currently having wide forested riparian zones would be of great importance.

Constructed/Restored Wetlands- Wetlands located at the interface of tributaries of Hardy Lake and the Lake itself are of great importance. They function as a natural nutrient uptake and provide an area for sediments to settle out during high flow events. Currently, many of the tributaries within the subwatersheds have wetland buffers. The sponsoring SWCDs should consider obtaining funds for the creation of additional treatment wetlands in areas which currently do not benefit from an interface wetland. At the same time, the SWCDs may consider the restoration of particular wetlands within the watershed. Efforts should be directed toward ensuring that existing Federal laws protecting wetland areas are enforced within the Hardy Lake watershed. Based on nutrient and sediment load data gathered in this study and/or the absence of wetlands, it appears Subwatersheds 8, 9, 10, 12 would benefit most from wetland construction/restoration projects.

Bridge Evaluation- Many of the tributaries which feed Hardy Lake have bridge crossings over county roads. Some of these areas may potentially be contributing an excessive amount of sediments due to washout during high flow events. Also, construction of new bridges often has a variety of stream impacts. During low flow periods, improperly placed culverts may act as barriers to fish passage. The Scott and Jefferson County SWCDs should consider meeting with the county transportation districts to discuss a corrective action in these areas. Stone rip rap and bank shaping can dissipate water energy and prevent excessive sedimentation and bank erosion. Not only would it benefit the watershed but would lower bridge maintenance costs associated with undercutting. This BMP should include the involvement of a consultant experienced in stream restoration projects. If done properly, these projects could address the erosion problems and add valuable in-stream habitat for resident fish and macroinvertebrate communities.

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